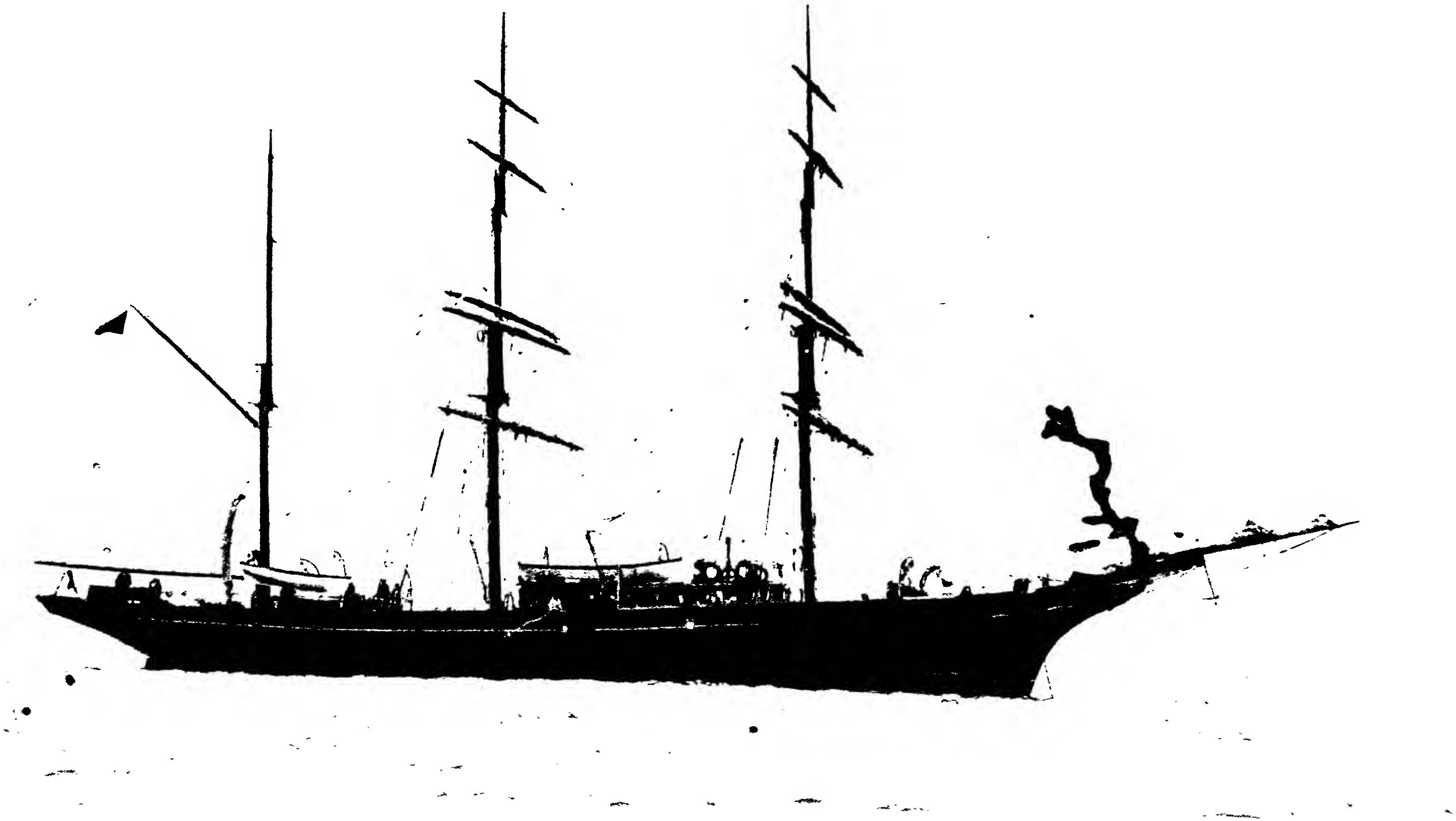
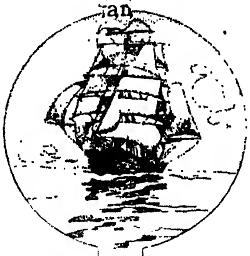


"Modwena," Mr. Thornton, one of the largest motor auxiliaries in the world. She is a 400-ton barque, 136ft. long, and fitted with a 200h.p. six-cylinder Gardner engine. There is also a 20h.p. engine for working the bilge pump, dynamo, etc. The vessel was built by John Reid and Co.

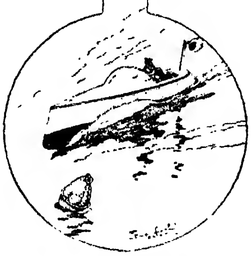
THE

Motor Boat Manual

THIRD EDITION



Compiled and Illustrated by the Staff of "The Motor Boat."



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INTRODUCTION.

IT was in January, 1907, that the "MOTOR BOAT MANUAL" first made its appearance. Prior to that there had been no book published dealing with marine motoring in all its branches, and our aim at that time was to produce a work dealing exhaustively with the new form of marine propulsion; exhaustively, that is to say, within the limits of a treatise on a pre-eminently practical subject, a book, we believe, of instruction for the absolute novice, and of reference for the experienced. Our endeavour, we are pleased to think, met with a great measure of success. Almost at once the MANUAL came to be regarded as the standard work on the subject, and in July of last year it became necessary to publish a second edition.

That, too, is now out of print, and it is partly on this account that the third edition is placed before our readers. But there is another reason. Progress of late has been rapid; boats and engines that, little more than a year ago, represented the last word in constructive skill are now out of date, and with them much of the "MOTOR BOAT MANUAL" has been left behind in the general advance towards perfection. The second edition was little more than a reprint of the first, the third has been completely re-written in many of its sections. Such chapters as those on knotting and splicing, and on the general principles of boat construction have, of course, been left unchanged; they deal with subjects that represent the accumulated experience of centuries, and the development of which probably approaches finality. But with many parts of the book the case is very different.

An entirely new set of designs, selected from the very best of the types they represent, has been substituted for the old. The various makes of engines and accessories are now specifically referred to by name in deference to the frequently-expressed wish of our readers. We have selected examples from the best of the motors marketed to-day, and in describing and criticising them have always endeavoured to keep the same object in view—to enable readers to discriminate in the choice of an engine for any special purpose, and to distinguish between good and bad practice, having regard to the work that has to be performed.

Pages might be filled in the enumeration of the various alterations and additions that have been found necessary, for plain as the progress of marine motoring has been, it was only on commencing the revision of the MANUAL that we ourselves realised how completely the old had been supplanted by the new.

For the rest, it need only be said that this edition occupies the unique position enjoyed by the first. It is the only exhaustive treatise on the subject, and it has been compiled by the staff of "THE MOTOR BOAT," which remains the only paper in this country exclusively devoted to marine motoring. The "MOTOR BOAT MANUAL," as now presented to our readers, is in accordance with the very latest developments of the sport and industry, and we launch it with the earnest wish that it may adequately meet the needs of changing times.

THE EDITOR.

January, 1909.

CONTENTS.

GENERAL PRINCIPLES OF HULL CONSTRUCTION.

Classification.

The chief object to be considered when designing a power boat of any sort is to get the best form of hull for the particular work to which the boat is intended to be put, and, at the same time, to adopt the most suitable construction for that work.

We may classify all power boats under the following headings:—

1. Light pleasure boats for inland waters.
2. Small sea-going boats, such as yachts' dinghies and launches.
3. Larger launches for estuary or sea, with or without cabins.
4. Heavy commercial launches and trading vessels.
5. Sea-going motor yachts and auxiliaries.
6. Racing launches.

The most suitable material for all the smaller power boats is, in our opinion, wood. Steel and other metals are frequently used for launch building, but for boats under 50ft. in length wood is cheaper, lighter, and more durable, weight for weight, than metal, unless the boat be very heavily built, and intended for exceptionally hard work in which weight is not of much account. We will, therefore, leave the construction of metal boats for future consideration, and only consider the various methods of wood construction, as applied to the foregoing types of boats.

Before dealing with the special forms of construction most suitable to each of the six classes enumerated above, it will be as well to get a general idea of the principal strains to which power-boats are subject.

Strains.

The chief strain on all motor boats, with the exception of heavy trading vessels and auxiliary yachts, is undoubtedly the vibration caused by the motor and propeller,* and this becomes worse in proportion as the power increases, or as the weight of the hull is reduced, being at its worst in light racing launches with high powers. It is also greater in boats which are practically open from end to end, without any thwarts or bulk-heads to tie the sides together, than in decked boats, or those which are fitted with proper cross ties of some sort.

As this vibration is almost entirely due to the motor, it is obvious that it will be greatest immediately under the motor bed, and will principally tend to work the centre of the boat up and down, although it has considerable side movement as well. To get rid of this vibration entirely, it is necessary that the hull should be very heavily built, with massive motor bearers thoroughly tied together and to all parts of the frame of the vessel, which should exceed the weight of the motor to such an extent that the latter has no power to move the mass of the vessel with its vibration.

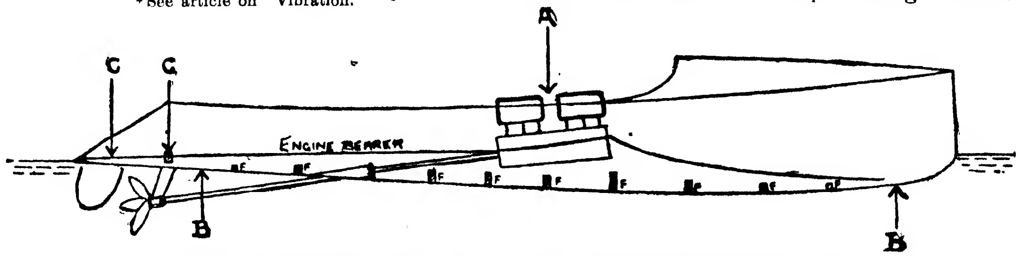
That it is possible to get the vibration down to such a point as not to be noticeable is proved by a number of existing craft in which it is almost impossible to feel whether the motor is running or no. In earlier days vibration was a noticeable feature of most motor craft, but vastly improved engine design and a better understanding of the science of balancing has practically eliminated the trouble at any rate in multicylinder motors.

Where the reduction of weight is of consequence, as in most launches, the vibration must be guarded against by careful consideration of the best form of motor bed to take up the strain, and if the design of the bed be right and the work good, there should be no difficulty in getting rid of the trouble.

The Motor Bed.

Probably the best form of motor bed is a pair of fore and aft bearers, extending from end to end of the boat, and carrying the motor between them. They should be as deep as possible just under the motor, the depth being reduced

* See article on "Vibration."



Diagrams illustrating the strains to be considered when designing a motor boat.

A, downward strain caused by vibration and weight of motor. B, B, upward strain when pitching in a heavy sea. C, C, side and twisting strain from rudder and propeller bracket. F, F, floor frames.

towards the ends. The thickness of these bearers should also be greatest at the motor, and they should be carefully fitted over a series of stout floor frames, extending right across the vessel from bilge to bilge, the whole being well bolted together and to the keel, with plenty of stout fastenings from the planking to the floor frames and bearers.

A good proportion for the bearers is that their depth at the motor shall be equal to at least one-third the distance they are spaced apart, and the thickness may be about one-quarter to one-sixth the depth, according to the proportionate weight of the motor to its power. If there be any doubt about the dimensions, it is better to err on the side of strength, and put in a bit more timber. The floor frames should be about one-third the depth of the fore and aft bearers with a thickness of one-third to one-fourth the depth, and they may be spaced the same width apart as the bearers, or even be put closer together at the motor, increasing the spacing and decreasing the size, as they approach the ends of the boat. It may be as well to mention here that a boat-builder would speak of moulding instead of depth, and siding instead of thickness, but the former terms are probably clearer to the general reader.

Pitching Strains.

For all sea-going launches, the vertical longitudinal strains caused by pitching and striking seas are, next to the vibration, the worst they have to encounter, especially in fast racing boats of a small proportion of depth and beam to their length, such as run in the unrestricted classes. Many of these boats have a proportion of only $8\frac{1}{2}$ beams to length, and as little as 18 depths to length, while the proportions of an ordinary sea-going yacht's launch would be about five beams to length and eight or nine depths to length at the outside. It is therefore clear that the boat of extreme proportions will be weak in a longitudinal direction unless special care be taken to meet these extra strains with proper strength of framing. Fortunately, the same form of construction used for the purpose of neutralising vibration will also give great longitudinal strength. That is to say, deep and long motor bearers will stiffen the boat enough to enable her to stand any strains caused by either pitching or vibration, provided they are well tied together and to the rest of the framing, with wood floor frames and plenty of fastenings.

Twisting Strains.

If we take vibration and longitudinal vertical strains as the most important points to be considered, we may then take the twisting and side strains caused by the propeller and rudder, and the thrust as the only strains of any great consequence remaining.

Of these, the thrust is a dead load in the fore and aft centre line of the boat, and, with a well-designed thrust bearing, should be entirely taken up by the fore and aft bearers and keel. Ball thrusts are generally used in motor boats, the "Hoffmann" thrust being one of the best both for design and workmanship.

The twisting strain on the stern, set up by the propeller, is of little importance in boats of the old straightkeeled type, where the stern tube passes through a nearly vertical stern post close to the propeller, but in a fast launch of modern cut-away design, with a long tail shaft outside the boat, and the propeller supported by a hanging bracket only, there is a considerable strain at the point where the bracket is attached to the hull, if the power be large. To provide for this, it is as well to have a fairly heavy floor fram or two at the point of attachment, tying the keel and sides of the boat together as rigidly as possible, and, if the fore and aft motor bearers extend far enough to be connected with these floors, so much the better. The same framing should be enough to take any strains from the rudder when the helm is put over suddenly at high speeds.

Deductions.

From the foregoing, we may deduce the following essential rules to be observed in designing all mechanically-propelled boats; viz., long and deep motor bearers, plenty of floor frames tying the bearers laterally. With such a frame, the timbers and planking may be kept fairly light, but, if the boat is to remain tight and to keep her shape, good workmanship is essential, however carefully the construction may have been thought out. The proportionate sizes of the various parts of the frame, as compared with the rest of the boat, will depend on the power and weight the boat has to carry, and whether she be for sea or river work.

It may be taken as a rule that in all sorts of motor boats there is no harm in putting in a good, heavy motor bed; in a racing launch it is absolutely essential if the boat is to have high power and hold together at all, that the bearers should be of ample strength and they may be augmented by the addition of steel plates as has been done in some launches, or to save weight a lattice system of construction may be adopted. In the ordinary pleasure launch it is equally necessary in a modified form to get rid of the unpleasant vibration, and for the sake of durability. For heavy towing and trading vessels, the form of the framing may be modified to suit any special requirements, but it is none the less requisite in some form or other, and for a boat built to carry cargo, with large hatchways, it is of the utmost importance that she should have plenty of longitudinal strength. The same remarks also apply to any vessels which have to take the ground often, or are intended to be carried in davits. For the fore and aft bearers, oak, mahogany, Oregon pine, or pitch pine are all suitable, while for the floor frames natural grown oak crooks are the best.

We have now discussed the principal strains common to all sorts of motor boats, and shown the form of construction best suited to resist them. Whether the boat be constructed of wood or metal, for racing or for river cruising, the same general form of motor bed is desirable, and it can be made equally well in metal as in wood.

Methods of Planking.

The exact details of the keel and other portions of the frame will be dealt with in the sections on each of the six classes of boats enumerated at the commencement of this article, but the various methods of planking are common to all forms of boat-building, and may be broadly divided into two totally different system, viz., clench or clinker-built boats and carvel-built boats. Modifications of these systems are shown in the sectional sketches (Figs. 1 to 5).

Clench.

The clench-built system consists in laying the planks on the boat in such a way that the lower edge of each plank overlaps the upper edge of the next plank below it, as in the case of a weather-boarded shed. The result is a series of inverted steps along the side of the boat, dying away at each end where the plank fits into a rabbet or groove in the stem and stern posts. This form of planking is very strong and light, and the seams will stand a lot of vibration without leaking; for this reason it is generally adopted for all beach boats and the smaller sizes of ships' and yachts' boats which have to be beached occasionally. It is

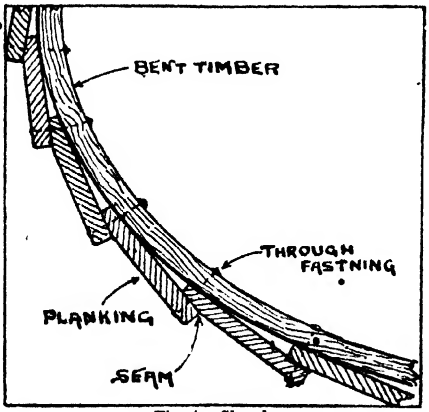


Fig. 1.—Clench.

also cheaper than any other form of planking, and is almost universally used for all sorts of rowing boats, and very small launches, both for sea and river use.

It is usual to plank clench-built boats on the building moulds before the timbers, or ribs, are bent into place, while with carvel-built boats, however small, the timbers are all bent over or under ribbands, which are temporarily fixed to the moulds before the planking is begun. Briefly, clench-built boats have the surface of the planking corrugated at the seams, while in carvel-built vessels it is (or should be) smooth; all large wooden vessels are carvel-built, although most steel ships and launches may be said to be clench-built, as the edges of the plates lap over each other as a rule.

Ship-lap.

There is one form of planking which is a compound of the two systems, though it is very rarely used on account of the great expense it entails. This is the ship-lap planking, in which

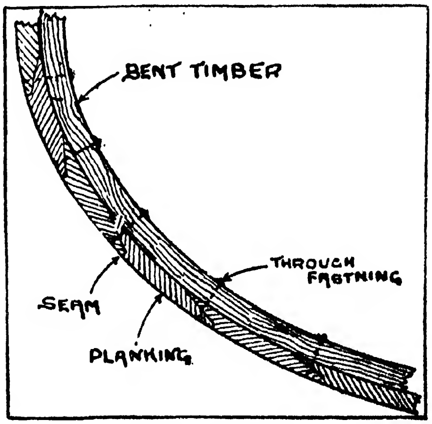


Fig. 2.—Lap-strake.

the lower edge of each plank overlaps the upper edge of the next plank below, and is through-fastened along the seam in the same manner as in clench-built work, but, instead of the edge of the upper plank standing out its full thickness beyond the lower plank, the two edges are bevelled off, and the edge of the upper plank is left about one-quarter of the total thickness, and let in flush into a rabbet in the lower plank. The result is a perfectly smooth skin, with seams that keep tight, as well as in ordinary clench-built boats, but the labour required is greater than for either clench or carvel building, while the strength at the seam is not so great as either of them.

Many of the very cheap clench-built boats are built entirely by eye, no design having been used at all, and, in some cases, upon nothing more than a midship half-mould. It is, therefore, hardly a matter for surprise that these boats are often very weird in shape, with strange lumps and hollows in the ends, hollow bows being a special weakness with this system—or want of system—of building.

Many people wonder why "Old Bob So-and-So" can afford to build launch hulls and sell them at 16 to 18 shillings a foot, when the neighbouring yacht builder asks from 25 to 40

shillings a foot for boats of the same size, and (to the uninitiated eye) only a little better in finish. But the matter is really very simple. The old man probably has a boy working with him at a few shillings a week; consequently, the total cost for labour for the two of them does not run to over two pounds a week, with, say, five to ten shillings a week rent for the shanty in which he works. He has never had any training to enable him to understand a design, and will probably be very scornful if the subject is mentioned, but he builds boats as his father and grandfather did before him, and doesn't know why they should be of any particular shape to suit certain purposes. The result of his work is a very cheap boat of whatever shape it may happen to come, which, for a fishing boat, or the commoner class of yacht's dinghy, might be quite good enough; but for a motor boat, something more than this is required if good results are to be obtained. Consequently the few pounds extra which must be charged for a boat carefully built to a design should not be grudged.

Carvel.

To return to our subject, we will now take the smooth, or carvel system of planking, and the next form of construction to be described is the

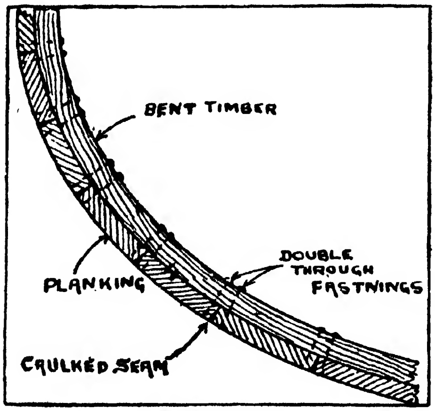


Fig. 3.—Carvel.

ordinary carvel build with a single skin, consisting of planks laid edge to edge, forming a seam, which passes right through the skin from inside to outside.

Such a seam, unless the edges of the two planks are fitted exactly to each other, would let the water through into the boat, and to prevent this leakage, it is usual to leave the seam wider on the outside, so that it can be filled with cotton yarn, driven in tightly with a caulking iron just below the surface. This cotton, or caulking, as it is termed, is then painted, and the seam filled with putty or some other form of stopping. The object of filling the seams with cotton is, that when the boat is in the water the cotton swells with the wet and completely closes the seam, in which it is assisted by the swelling of the planks as they soak up the water.

The chief objection to an ordinary carvel-built launch of small size is that unless the timbers, or ribs, are very close together, the caulking is liable to be loosened by the vibration of the motor, and so cause trouble, added to which it is very difficult to caulk a seam if the planking be under half an inch in thickness.

To overcome this difficulty, the timbers may be reduced in size and placed very close together, to support the edges of the planks better and to prevent one edge working on the other. In addition to this, a few of the highest class of builders fit the edges of the planks so carefully together that, combined with the use of close timbers, there is no need for any caulking at all, the edges of the planks being merely varnished as they are put together. The method by which such a perfect fit is secured is as follows :—The edge of the new plank is roughly cut to the shape of the edge of the one already fitted in place, and the latter is then covered with chalk before the new plank is tried up in its place, so that it will leave a chalk mark on every part of the edge of the new plank where the two touch. All these chalk marks are then planed off, and the plank tried up again; the operation being repeated until the chalk from the fixed plank marks every part of the edge to be fitted to it. The upper edge of the new plank is then shot fair with a jack plane, and it is ready to be fastened in place, this being done in the fitting of every seam and joint in the boat.

A boat built in this manner is, of course, very costly, as the labour is enormous, and only the most skilful workmen can do it. But the result is a much stronger boat for a given weight of material, and the finest surface imaginable, as no putty is used anywhere, even the nail heads being filed off flush with the planking instead of being punched below the surface and puttied over as usual. The greatest objection to this method, in addition to its cost, is that if the boat be out of water for any length of time the planking will dry, and the seams will consequently open as the wood shrinks, causing bad leakage when the boat is first put into the water again, although she will soon swell up and be as tight as ever. To remedy this evil another form of seam has been largely used, termed ribband carvel.

Ribband Carvel.

This consists of a ribband or strip of wood, of more or less rectangular section, placed on the inside of the seam, and extending the whole length of the boat. If small bent timbers are used, they are let flush into the ribband (Fig. 4), but if deeper cut or shaped timbers are used the ribband is kept flat and thin, and is let into the timbers (Fig. 5). In ribband carvel

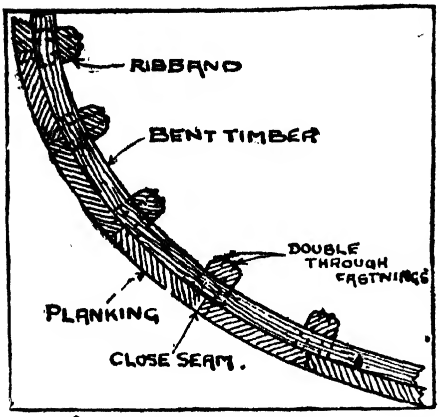


Fig. 4.—Ribband carvel.

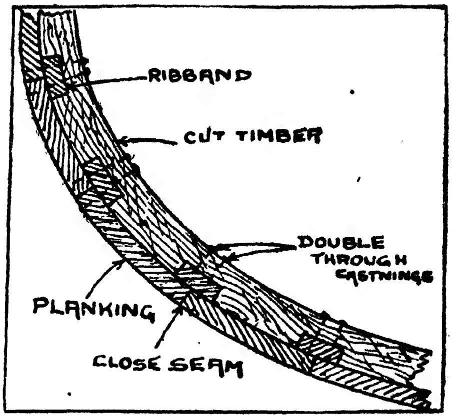


Fig. 5.—Ribband carvel.

work it is usual to space the timbers much further apart than in ordinary carvel, and two or three times as far apart as would be necessary in the close-timbered carvel previously described. This is on account of the extra strength imparted to the seam and to the whole structure by the ribband, which, greatly increases the strength of the hull longitudinally, but it is a common fault to over-estimate this increase of strength, and to place the timbers too far apart, causing the planking to straighten between the ribbands for want of sufficient transverse support from the timbers.

A fairly good rule for proportion of timbers to planking is to make the sectional area of the timber equal to 1½ times the square of the thickness of the planking. That is to say, if the thickness of the plank is ½ inch, then the size of the timbers, if bent, should be not less than ½ inch moulded by ¾ inch sided, or, better still, 9-16 by 11-16 inch in section and spaced 5 inches apart from centre to centre, or ten times the thickness of the plank.

If cut or shaped timbers are used, the moulding must be much greater in proportion than with bent timbers, probably twice as much, while the siding will generally be the same, but the spacing of the timbers will be doubled. For this reason the strength is much more evenly distributed over the planking with bent timbers of a given weight than with cut timbers, although the latter are more rigid. Another great objection to the use of cut frames is the difficulty of obtaining oak grown to the exact curve required for each part of the boat, and unless the timber is grown to shape it is practically useless. One of the worse faults of many of the river builders is the use of straight-grained oak for work where crooked timber should be used, especially in the case of stems and knees, and this is not confined to cheap work, but is quite common in the most expensive boats on inland waters.

Another variety of the ribband carvel idea is to build the boat in the ordinary carvel style and then cover the seams between the timbers with short thin strips of wood fitted in afterwards; this is very troublesome to do, and not nearly so strong as the regular ribband carvel work previously described.

Other Methods.

There are several other methods of keeping the seams tight, such as laying strips of brass between the timbers and the planking over the seam as in some Canadian canoes; or the edges of the planks are tongued and grooved. In some cases both edges are grooved, and a brass tongue fitted, but none of these are worth the trouble and expense entailed. A better way is to bruise a groove in the upper edge of each plank, and then plane the edge away until the groove just disappears, so that when the boat is in the water and the plank swells with the wet, the portion of the edge which was forced down into the wood can now swell up and close the joint tightly, remaining above the rest of the wood even when the boat is hauled out and dried. However, it is very troublesome to do, with the great danger of spoiling the edge of the plank, but, if well done, this method gives excellent results.

Limber Holes.

Whilst the close-timbered carvel system of planking is probably the lightest form of construction known, it has the serious objection of opening badly when the boat is out of the water, in addition to which the junctions of the heels or lower ends of the timbers with the keel form shallow pockets, each of which will retain a small quantity of bilge water whenever the boat is pumped out, unless the whole of the surface be gone over carefully with a sponge to absorb each separate pocketful of water. This water, if it be allowed to remain constantly in the angle between the timber and the keel, will, in time, cause the planking to rot, or, at any rate, it will render it

discoloured and sodden. It is usual in large vessels to cut a small limber hole or water-course between the timber and the planking, but, where the sizes of the timbers are as small as those at present under consideration, it would not do to sacrifice any portion of their strength by cutting limber holes.

The foregoing objection applies even more strongly to ribband carvel planking, as the latter not only has the same closed angles between keel and timbers, but it also has the additional pockets caused by the intersection of the timbers with each of the ribbands, thus increasing the trouble nearly ten-fold.

If limbers be cut in the face of the ribbands before the boat is planked, then there is the probability of a leak at each of these places, owing to the continuity of the surface of the ribband at the back of the seam being broken, and so letting in any water which may get through the seam.

Multiple Skin Construction.

There is, however, one system of planking which has none of these objections to it, and, in addition, is very rigid and durable, being especially adapted for use in boats which are much exposed to the weather or to the heat of the sun in tropical countries.

This is the multi-skin construction, which has many varieties, from the ordinary Government pattern two-skin diagonal building, as used in the Admiralty pinnaces and vedette boats, to the four and even five-skin construction used in the Saunders' sewn system.

Double Skin.

The simplest form is that in which only two diagonal skins are used, the planks in one skin crossing those of the other skin at right angles, but both sets of planks being at an angle of about 45 degrees to the keel of the boat. The inner skin is laid first over the usual moulds and ribbands, one or two of the latter being allowed to remain in the boat permanently; then a sheet of cotton is stretched tightly over the outside of the first skin after it is well coated with thick paint or varnish, the cotton being itself well painted or varnished as soon as it is in place, and a coat of paint being laid under each plank of the outer skin as it is fastened in place.

The two skins are then closely fastened together with copper nails, clenched over roves, or burrs in the usual way, as shown in the accompanying diagram (Fig. 6).

This method of planking, with several skins in which the planks run in different directions, entirely obviates the use of ribs or timbers, with the exception of the floor frames, which are common to all forms of construction. It requires, however, a considerable amount of skill on the part of the builder, as careless work will not only result in a leaky boat, but will also probably result in a series of buckles or swellings in the outer skin if the planks be not properly fitted.

Double skin diagonal planking and double fore and aft planking, or a combination of diagonal and fore and aft, are none of them new by any means, having been in use in one form or another for the last 40 or 50 years, but the use of three or more skins is comparatively a recent practice.

Triple Skin.

In 1896 the writer designed a boat for the Mediterranean regattas, which was built with an inner transverse skin running right round the boat from gunwale to gunwale at right angles to the keel, and tapering from $\frac{3}{8}$ inch in thickness at the keel to $\frac{1}{8}$ inch at the gunwale at each side. This was covered with a sheet of painted cotton, and then an intermediate diagonal skin of 3-16th inch was laid, running at an angle of 45 degrees from keel to gunwale raking aft, and also covered with a similar sheet of painted cotton. Over this was placed an outer skin of $\frac{1}{4}$ inch fore and aft planking, as shown in the diagram (Fig. 7). The whole three skins were closely fastened with light copper nails, clenched on roves, and spaced $1\frac{1}{2}$ inches apart all over the planking, about 15,000 fastenings being used in the planking alone for a boat 33ft. over all.

The great defect in this first boat was that the ends were weak, owing to the fact of the inner skin only extending over the middle half of the boat's length; consequently the ends, especially the bow, had to be strengthened after a season's racing, but the centre of the boat, where the greater part of the strains were located, stood perfectly, and is still in fairly good condition at the present time.

This is probably the best system of building for all boats,

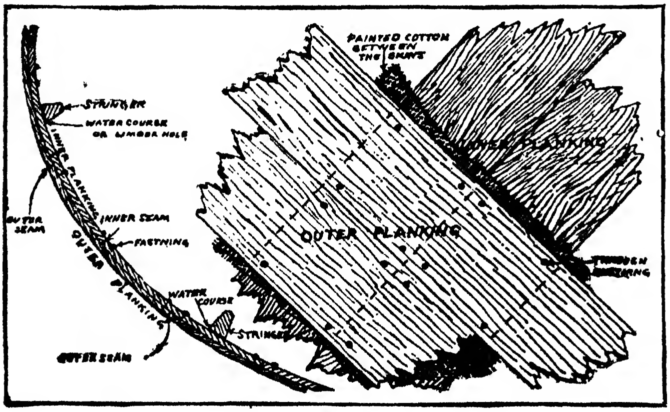


Fig. 6.

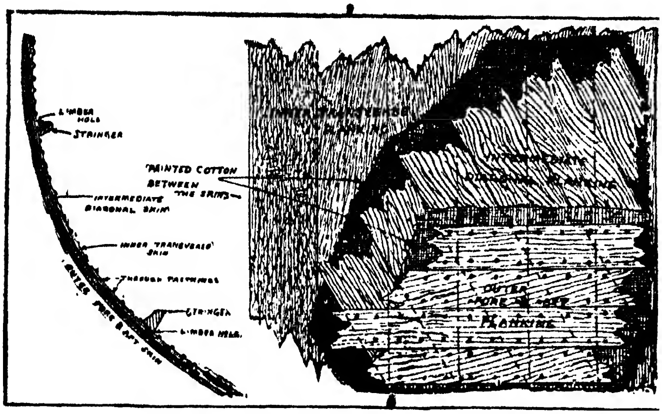


Fig. 7.—Triple skin.

whatever purpose they may be intended for; but, except in the case of high-powered launches, the advantages hardly justify the great increase in the cost of construction.

The Copper Sewn System.

The Saunders' patent-sewn construction, shown in the diagram (Fig. 8), is precisely similar to the above, with the exception that instead of using copper nails clenched on roves, or turned on the inner planking, the fastening is accomplished by means of stitching the skins together with bronze wire passing through holes bored with an electric drill, the outer portion being let in flush with the surface of the wood by means of another electric tool. The result is an exceedingly strong, light, and durable form of building, most suitable for all sorts of motor boats, and especially for the big racing launches. As to whether the sewing is superior to the old method of fastening with nails, it is very difficult to give an opinion. Probably there is not very much to choose between them, each having some advantage over the other.

As to weight, it appears probable that very light, close-timbered, ribband carvel may be a shade lighter, strength for strength, than any other form, but for general excellence and durability the multi-skin construction is undoubtedly the best.

Woods Used in Construction.

Having dealt with the different methods of planking generally used in the construction of motor boats, we must now consider the various woods employed for each part of the boat. In the following list, the most suitable wood for all classes of general work is placed first, although in many cases other woods are better for the special conditions arising, where boats are built for some particular class of work out of the ordinary run.

The various parts of a launch hull, with a list of woods generally used for each part.

Keel.—American elm, oak, pitch pine, Oregon pine, Kauri pine, larch, and, in large seagoing yachts, English elm is frequently used with good results.

Stem and stern post, floor frames, and wood knees.—English oak (natural crooks), or larch (if natural crooks can be obtained). Note.—Steel floor frames, if galvanised, may be used with advantage in large craft.

Engine bearers.—Oak, pitch pine, and Oregon pine.

Timbers (bent).—American elm. Ash and oak are occasionally used, but are not very suitable.

Timbers (cut).—English oak (natural crooks), and larch (natural crooks) are the only woods suitable for this work obtainable in this country.

Deadwoods and false keels.—Oak, English elm, and larch are all suitable for both purposes, white pitch pine, Oregon pine, and Kauri pine may be used for false keels only.

Gunwale, inwale, or shelf and stringers.—American elm, Oregon pine, pitch pine, mahogany, and, in large yachts, oak.

Deck beams and carlines.—Oak, larch, pitch pine, Oregon pine, and Kauri pine.

Planking.—Mahogany, cedar, teak, oak, pitch pine, Oregon pine, Kauri pine, yellow pine, white pine, and larch, with American elm and English elm for the lower strakes in seagoing vessels.

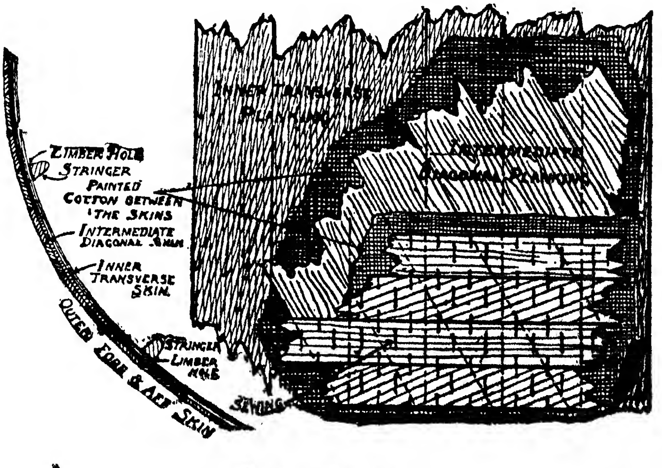


Fig. 8.—Sewn system.

Deck.—Kauri pine, yellow pine, cedar, white pine (if covered with painted cotton), and for heavy sea-going work in hot climates teak is frequently used.

Coamings.—American elm, mahogany, and teak.

Covering board.—Where the deck is laid in narrow planks, a teak or mahogany covering board should be fitted; and in some cases a centre plank as well.

Thwarts and other seats.—Teak or mahogany, and, in cheap work, Oregon pine.

Bulkheads.—The same as for seats, except that cedar may be used in very light craft, and plain red pine match-boarding in cheap work.

Flooring and floor bearers.—White pine is almost universally used for flooring in all classes of power and sailing craft except where American elm or teak gratings are fitted. Risings and moulding should be of mahogany or teak.

Rudder and tiller.—The rudder and steering gear in most launches would be of steel or bronze, but in small motor dinghies and square-sterned yachts' launches it is usual to fit an oak or teak rudder, with an ash or American elm tiller.

Notes on the Selection of Timber.

Oak.—British-grown oak is far superior to any of the foreign oaks for all ship and boat-building purposes where crooked timber is required, but German and American oak may be used for straight work, where toughness is not quite so essential. The light-coloured oak with a fine grain is usually the toughest, and, if possible, it should be felled in the winter. Be careful to see that there are no sappy places or bad shakes in the wood, and that it is not of a dark-reddish colour with an open grain. Oak is the most durable wood used in shipbuilding.

American Elm.—The rock elm is the best variety, and should be very white in colour and extremely close-grained. It can be obtained in long lengths, and should be free from knots and shakes. It is the toughest wood known to shipwrights, but it is not suitable for any planking, where it will be alternately wet and dry, as, under those conditions, it is very liable to rot, and also to warp. Under sea water it is extremely durable, but it does not last so long in fresh water.

Teak.—Teak is the most durable wood known for plankings, skylights, hatchways, seats, and all sorts of deck fittings of this nature, but for ordinary launch work its weight puts it out of the question, except for seats and rubbing bands, etc. It can be obtained in very long lengths, but is very expensive.

Mahogany.—Honduras and other South American mahoganys are probably the most suitable woods for all launch planking, as they are hard, durable, fairly light, and can be obtained in planks of great length and width, clear of knots and shakes. The finer the grain and the lighter the colour the better, as a rule.

Cedar.—For very light racing launches, where only one skin is used, cedar is undoubtedly the most suitable wood for planking, deck, and bulkheads, but it splits easily in the sun, and soaks up a lot of water unless the boat is hauled up to dry frequently. It is extremely light, and fairly tough and durable for its weight. Like mahogany, cedar may be obtained in great lengths and widths; the lighter colours are the lightest in weight as a rule, but the darker red varieties keep their colour better, and are more durable. Cedar and mahogany come next to teak in price.

Pitch pine.—A very tough and durable wood suitable for the planking of sea-going launches intended for rough work; also for the keels of light racing launches and for gunwales and stringers in any class of boat. It is rather heavy and very bad to work, owing to the resin clogging the tools. It is a cheap wood, but must be chosen with care to avoid bad knots and sap. Any length up to 50 feet can be got without much trouble.

Oregon pine.—Similar to pitch pine, but much lighter and not so strong or durable: easy to work and tough, and is very suitable for all work where pitch pine is too heavy and great durability is not quite so important. It is superior to pitch pine for most boat work.

Kauri pine.—About the best wood for decks, and very good for planking, but it is rather heavy for its strength when compared with mahogany and cedar for the latter purpose.

Yellow pine.—This, with cedar, is the lightest wood known to boat builders, and is generally used for decks, although it is not nearly so durable as Kauri pine. It is frequently used for planking clench-built boats. It can be got in considerable widths, but is expensive.

White pine.—The usual wood employed for the planking of clench-built boats and for decks which are to be covered with painted cotton. It is very light, and much tougher than yellow-pine or cedar, but it has many small knots and rather a strong grain, as a rule. It is not so good for carvel planking, as the edges may curl and show the seams badly, but it is the most suitable wood for flooring, and is very cheap, although it cannot be got in lengths over 14 to 15 feet by 9 to 11 inches, as a rule.

Larch.—Larch is one of the best boat-building woods grown in this country, being extremely tough, durable, and fairly light, with either straight or crooked grain, but, unfortunately, it is very scarce in the South of England.

Elm.—English elm is only suitable for keels, deadwoods and planking below water-line of vessels intended for sea use only, as it soon rots in fresh water. It is also unsuitable for the keels of small boats. Great care must be exercised in choosing elm, as it is frequently full of bad knots and shakes. Sap is not so important in elm as in any other wood. The light-coloured wych elm is much tougher than the ordinary variety.

SOME TYPICAL DESIGNS.

After the foregoing brief review of guiding principles, the reader will be in a position to appreciate the following examples of their application. A series of first-rate and modern designs will now be described, accompanied by complete specifications, a careful study of which will serve to show what special points have to be taken into consideration when placing an order. We will deal first with a light river launch, then will follow a powerful dinghy suitable for carrying in davits aboard a yacht. After that it will be convenient to consider a sea-going pleasure launch. That will suffice for the purely launch type; we purpose then to consider the more important classes of motor craft, cruisers (auxiliary and full powered). Of these, the first example will be a little single-handed auxiliary; then will be given a rather larger boat of the same type; following this an auxiliary fishing yacht will be considered. All these boats have motors auxiliary to the sails; the next example will be a motor yacht with an auxiliary rig, and, lastly, a full-powered motor yacht fitted with twin screws, so that, should one engine break down, the other will serve as a stand-by in lieu of sails, and enable the boat to reach her destination.

A 35ft. River Launch.

This boat, "Viatic II.," was designed and built this year by Messrs. Hart, Harden and Co., Hampton Wick, for an owner who was one of the first to possess a light, fast Thames launch. She was intended primarily for use on that river, and accordingly lightness of draught and extremely clean-running qualities have been made the chief consideration. She has accordingly plenty of length, not very much beam, and fine, easy lines. Had she been intended for "ditch crawling" or destined to be handled by one less used to the river than her owner, she would no doubt have been provided with a skeg, but this, it will be noticed, is absent, and, under the circumstances, it is unnecessary.

There is only a short length of deck fore and aft, thus leaving a maximum of accommodation, while the engine, a 30h.p. Belsize, is situated well forward and protected by a cover. A spray hood is, of course, unnecessary. Another interesting point is the position of the rudder. It is well forward of the propeller and set over to one side, the object being to give the greatest possible ease of manœuvring. A river launch has, naturally, constantly to negotiate locks, and on such occasions the reverse comes frequently into use. Now, with the rudder immediately aft of the propeller, many boats, especially those with a flat run, such as "Viatic II." possesses, will not steer astern, but are dragged wildly over by the action of the propeller, which takes the water away from the rudder. With the present arrangement this difficulty is got over, and the boat should steer astern very nicely. We have dealt with the point rather fully, because this quality of steering astern is a very important one on the river. It is in a lock where the most delicate steering is required. The tumble home of the stern is also a desirable feature for a launch of this class. She is sure to be bumped occasionally by skiffs and other craft coming up astern, and with a straight stern or one with only a slight tumble home every contact would make a visible mark, whereas the "duck bill" form of stern can be fitted with a brass rubbing strake on the water line and will show no marks. The boat is 35ft. long, 5ft. beam, and 2ft. total draught. The following is her specification:—

Specification of River Motor Launch.

Dimensions.—35ft. overall length, beam 5ft., draught (total) 2ft.

Keel.—Pitch pine, 2in. moulded forward, tapered to 1¼in. aft, 5in. sided amidships, tapered to siding of stem and stern frame, rabbeted to receive planking.

Stem.—English oak, grown crook, 2in. sided, 3in. moulded at sheer, 4in. at water line, tapered to moulding of keel, properly scarphed to keel, and rabbeted to receive planking.

Deadwood.—English oak, grown crook, 2½in. sided, 3in. moulded at throat, securely fastened with 5-16in. copper bolts to keel and stern and clenched on copper rings.

Stern frame and knee.—English oak, grown crook, 2½in. sided, moulded to plan and fastened with 5-16in. copper bolts to keel, clenched on copper rings.

Chine pieces.—American elm, 2½in. moulded and 2in. sided, properly steamed to required shape, securely fastened to stern frame with 12 gauge brass screws and scarphed at fore end to

receive bilge stringer, and to be rabbeted on top and bottom edges and bevelled to receive topside and bottom planking, wing knees to be fitted on outside edges of keel and fore edges of chine pieces.

Intermediate stern frames.—English oak, 1in. sided, 2½in. moulded, spaced out on radius of chine and shelf pieces, not more than 6in. centres, and to be securely jogged into same at head and heel and fastened with 10 gauge brass screws.

Timbers.—Selected rock elm, 9-16in. moulded, ⅝in. sided, spaced, 3½in. centres, to be steamed in one length gunwale to gunwale, extending from stem to fore end of chine piece, thence aft to be jogged into chine and shelf, heads and heels, to be through copper fastened on each edge of keel and properly riveted.

Planking.—Clean, selected Honduras mahogany or Kauri pine, free from shakes and sap, worked in not more than 4in. widths clear of bilges and not more than 3in. at turn of bilges, to be properly through fastened at each bent timber and shelf on top and bottom edges with 14 gauge copper nails, and to be riveted on copper roves on face of timbers, and to be fastened at hood ends and stern frames with 1½in. by 8 gauge brass screws on top and bottom edges of plank and into chine rabbet, planking to be cut ½in. ordinary and to be properly butt-scarphed on timbers, butts to be not less than 5ft. apart with exception of shaped strakes round stern, close joint seams for mahogany plank or a three-thread caulking seam for Kauri pine planking.

Shelf.—Pitch pine or Oregon pine, clean and free from knots, to be in one length from stem to fore end of cut stern shelf frame, where it should be long scarphed and clamped on inside and through copper fastened. Shelf to be 1½in. sided, 2in. moulded amidships, tapered at fore end to 1in. sided, 1½in. moulded, and after end to size of stern frame, and to be faced with ⅜in. mahogany inside.

Floor frames.—English oak, grown crooks, 2in. sided, 2½in. moulded at throat, tapered at ends and extending to bilge stringers, spaced 2ft. centres in way of motor and reverse gear, and one to be fitted in way of stern tube, intermediate floors 1¼in. sided, 2in. moulded at throat, spaced not more than 4ft. apart, extending from stem to stern, arms of floors to be carried out to bilge stringers, the whole of the floors to be bolted through main keel at throat with 5-16in. and ¼in. copper bolts respectively and clenched inside on face of floors with copper rings, arms of floors to be through fastened with 10 gauge copper nails and clenched on copper roves.

Bilge stringers.—Pitch pine or Oregon pine, 1¾in. sided, 1¼in. moulded, worked in one length from stem and to be properly long scarphed into chine pieces, and to be through copper fastened at every third bent timber and clenched on copper roves.

Breast hook.—English oak, grown crook, 1½in. sided, 5in. moulded at throat and 12in. arms, to be through copper bolted to stem at throat and clenched on copper ring inside.

Deck beams.—Two main beams at bulkheads, of oak, sided 1½in., moulded 2in., intermediate beams of pine, sided 1in., moulded 2in., shaped to suit 3in. camber amidships, spaced 12in. centres, ends of beams to be dovetailed into shelf and a clamp piece worked under ends of beams and shelf, through copper fastened to timbers.

King planks.—Pine, ¾in. moulded, 5in. sided at inboard ends, tapered at fore and after ends to 3½in., to be let into top of beams and screwed or nailed into same, and cleaned off flush with beams.

Coaming chocks.—Oregon pine, 2in. sided, moulded out to form circular ends of well, secured to main beams and shelf with 10 gauge brass screws.

Bulkheads.—½in. mahogany, to be fitted at each end of well and dummy panelled, to suit side panelling, with door at each end.

Linings.—The whole length of well to be lined with selected ⅜in. mahogany, the same to be faced with suitable mouldings and rails to form dummy panelling, top and bottom rails to have proper spaces cut for ventilation.

Covering boards and centre deck planks.—Of selected ¾in. mahogany, moulded to form of deck plan, overlapping on outside edge ⅜in. and rounded to form moulding; one long length to be worked amidships and properly butt scarphed to forward and aft shifts, the whole to be securely fastened on both edges to shelf and sheer strake with 1½in. by 10 gauge brass screws let down and dowelled, centre deck planks of ¾in. mahogany, 4in. sided at inboard ends, 3in. sided at outboard ends, fastened to each deck beam with 1½in. by 10 gauge brass screws let down and dowelled.

Decks.—Of clean, selected ¾in. Kauri pine, free from shakes, to be properly laid in tapering widths not to exceed 3in. at inboard ends, edges to be properly fitted and dowelled between each beam, and secret nailed to every beam, a four-thread caulking seam to be allowed, the whole to be properly laid, caulked and payed with marine glue and cleaned off.

Motor beds.—Of clean Oregon pine, carried 6ft. forward of engine and from engine to stern frame, to be 2in. sided and moulded to fit on face of bent timbers and jogged over grown floor frames, to be through copper bolted with ⅜in. copper at each 2in. floor and 5-16in. copper at intermediate floors, bolts to be clenched on top edge of engine beds with copper rings, let down flush, the after ends of engine beds to be jogged into stern framing and securely fastened, cross bearers to be fitted between engine beds and angle chocks or knees to be fitted on outside of bearers and carried out to bilge stringers to prevent racking, bearers and knees to be spaced as follow: one at fore end of beds, one at fore end of engine, one at stern tube chock,

and one at rudder tube, the whole to be securely fastened to engine beds and stringers.

Floor bearers.—Of pine, 1½in. sided by 2in. moulded, ends to be bevelled off to fit bilge stringers where possible, centres to be supported by upright 1½in. by 2in., fixed to timbers and jogged under bearers, except in the way of shaft, where uprights must be fitted each side of shaft.

Flooring.—Of pine, ⅝in. by 6in., to be laid parallel and carried out to side panelling, joints to be left with ⅛in. clearance to allow for swelling, to be rubbed down and painted on top and bottom surfaces and fixed to floor bearers where necessary with 1¼in. by 10 gauge brass screws.

Stern tube chock.—Of Oregon pine, 5in. sided and moulded to suit pitch of stern tube, to be securely bolted through main keel with 5-16in. copper bolts, clenched on copper rings inside chock, to be bored out dead true to shaft line and to external diameter of stern tube.

Rudder.—Stem to be of 1in. forged steel bar with straps welded to stem and carried well down, blades tapered at ends and riveted through, blades to be cut from ⅛in. mild steel plate to shape required, stern to be fitted with ⅞in. steel tiller, under deck to be fitted with sliding gimbal sleeve piece to carry steering wires, stern of rudder to be carried through deck and fitted with metal tiller strap and wood tiller and metal acorn nut on top, the whole of the steel work of rudder to be properly galvanised.

Steering gear.—Wheel columns to consist of inner brass tube 1in. diameter, fitted with shouldered metal plug at bottom end, metal back nut bored out, a substantial angle plate to be fitted on side of engine beds and securely bolted to same, angle plate to receive inner tube plug and fixed stationary by back nut, outer wheel column to consist of brass tube 1¼in. diameter, bushed to fit over and revolve on inner tube, 14in. car type steering wheel with brass centres fitted to outer column and to have Bowden controls fitted, with actuating wires leading through inner column and connected to ignition and carburetter levers, ⅜in. flexible steel steering wires to be supplied leading from tiller sleeve to hard wood drum 4in. diameter fitted and pinned to outer column, with ⅛in. brass flanges 6in. diameter fitted and fixed to wood drum, wires to be carried through galvanised sheaves of 3in. diameter where necessary, one 5in. galvanised turnbuckle to be fitted on each wire for taking up slack.

Deck fittings.—Brass or gunmetal stem band cast to stem head, tapered to ½in. round on face of stem, widened out to width of keel under forefoot, carried 18in. beyond scarph of stem and to be thinned down at end and let in flush, to be fastened to keel and stem with brass screws, one gunmetal or brass bollard cleat on fore deck and bolted to king plank with metal bolts, two metal fairleads forward for head lines, one metal socket for burgee staff, one metal socket for headlight stanchion, one metal pillar cleat fitted on each quarter, one metal flagstaff socket for ensign staff.

Painting.—The whole of the woodwork to be well rubbed down and coated inside below flooring one coat red lead priming, two coats red oxide paint, all top work and decks and outside above water line to receive five coats best yacht copal varnish, below water line two coats red lead priming, two coats finishing colour, and one coat anti-fouling composition.

Sunk moulding and gilding.—To be worked on sheer strake from stem to stern and to be properly gilded throughout.

A Yacht's Tender.

We have now to consider a powerful yacht's launch, designed for a good turn of speed combined with strength and seaworthiness. Such a boat has, of course, to be carried in davits, and must be available for almost any sort of work from towing to running passengers or stores to and from the shore; she will be used in all weathers, will do a good deal of bumping alongside, and must be altogether a stout knockabout job. Lastly, it is of importance that she should be a dry boat, for the benefit of smartly-dressed passengers.

The design now before us fulfils these requirements. She is a 22ft. boat, fitted with a 15h.p. Gardner petrol motor, and is from the board of Mr. A. Sheppard, A.M.I.N.A. She has powerful lines, with great flare and lifting power in the bow, while to make her a dry boat she has been given a good deal of rocker, which will cause her to trim by the stern when running fast. She is a boat that could take the ground without coming to any harm, the keel being deep and carried right down to a skeg to protect the propeller. The davit slings can be seen coming through the seats fore and aft, being carried right down to the engine bearers. These latter run practically the whole length of the boat, and, combined with the deep keel, give the necessary longitudinal strength to enable the boat to be carried in davits.

It will be noticed that the petrol tank and a deck beam divide the passenger accommodation from the engine space, and this beam is further utilised as a guide for a tow rope, enabling it to clear the tiller aft.

There is one special and original fitting in this boat that we do not remember to have seen before. Forward of the engine is a dynamo, which can be utilised to charge the accumulators of the lighting installation aboard the yacht. While driving the dynamo the engine is disconnected from the propeller, and it stands to reason,

of course, that while running the boat must be lowered into the water or draw circulating water from some specially devised source. The arrangement is an excellent one, for it relieves the passengers of the parent vessel from any slight annoyance that might be caused by an engine on board running for hours on end while lying at moorings. Under this system the boat could be dropped astern on a long painter, only the cables carrying the current being brought aboard.

Specification.

Dimensions.—Length over all, 22ft.; breadth extreme, 5ft. 6in.; depth moulded, 2ft. 7in.

Hull.—To be carvel built of cedar or mahogany, with planks in one length of $\frac{3}{8}$in. thickness; to be copper fastened throughout, those in the keel, deadwoods, and timbers to be clenched on rings. All seams to be carefully caulked with best cotton and stopped.

Keel.—Of American elm, 2in. thick, moulded according to plan.

Timbers.—Of best American elm, $\frac{3}{4}$in. by $\frac{1}{2}$in., spaced 6in. centres, continuous from gunwale to gunwale. In way of motor five American elm frames to be increased to 3in. sided and $\frac{5}{8}$in. moulded, all up and down. Also about seven extra-grown oak floors, $1\frac{1}{4}$ by 1in. at centre, tapering to ends to be fitted in position as shown by general arrangement plan.

Stem, etc.—Stem, stern pieces and knees to be of well-grown English oak.

Thwarts, etc.—Thwarts and cockpit seats to be of cedar, $\frac{3}{4}$in. thick.

Gunwale piece.—Of American elm, 2in. by $\frac{3}{4}$in.

Rubbing piece.—Of American elm, $1\frac{1}{8}$in. by $1\frac{1}{4}$in.

Covering board.—Of elm, $\frac{3}{8}$in. thick.

Rising.—Of American elm, $\frac{3}{4}$in. by $\frac{3}{8}$in.

Bilge stringers.—Of pitch pine, 1in. by $1\frac{1}{4}$in., carried all fore and aft.

Hogging piece.—Of American elm, $4\frac{1}{2}$in. by $\frac{3}{4}$in.

Deck beams.—Of pine, $1\frac{1}{2}$in. by $\frac{3}{4}$in., spaced 12in. about.

Floors.—Of pine, $\frac{5}{8}$in. thick.

Motor and dynamo bearers.—Of pine, carried all fore and aft, well fitted, and secured to hull with screws.

Motor casing.—To have a neat mahogany cover, as shown in general plan, worked with watercourses under the joints, and fitted with brass circular lights. The sides and ends of cover to have removable "louvres" fitted to ensure a good supply of air reaching the engine and carburetter. The whole casing to be made of good material and workmanship to approval.

Decks.—Of best selected yellow pine in 2in. widths, tapering to ends.

Hull.—The outside to be well rubbed down and varnished with four coats of best copal varnish, with gold line in hollow moulding and Yacht Club badges on bow. Inside to receive three coats of varnish, and bilges to be coated with Blake's "Algicide," or other approved composition.

Gratings.—Of American elm, as required by plan, of $\frac{3}{4}$in. or $\frac{7}{8}$in. mesh.

Cleats, etc.—Cleats and fairleads to be of polished gunmetal.

Spray hoods.—To be fitted, with galvanised iron spreaders and hoods complete, both fore and aft.

Sheets.—Fore and stern sheets to be kept wide and low, and fitted with cushions, as shown by plan.

Tiller, etc.—One tiller and one gunmetal steering wheel to be fitted according to plan.

Staffs, etc.—One ensign staff, one burgee staff, one boathook with gunmetal head, painter and bailer, one pair of ash oars, leathered and coppered, one pair of gunmetal crutches.

Slings.—Galvanised iron hoisting slings of 7-16in. diameter, chain or bar iron, fitted and thoroughly through bolted to keel and chock for hoisting launch in davits of barge-yacht. Spread of davits, 15ft.

Tanks.—Copper petrol tank to be fitted as shown on plan; to be of about 20 gallons capacity. All fuel pipes to be of solid, soft-drawn copper tubing, well guarded and protected from damage.

A 30ft. Steel Launch.

The steel motor launch "Norvic" was designed in 1908 for Mr. J. Dawson Paul, of Norwich, by Mr. James A. Smith, M.I.N.A., and was built by Messrs. Boulton and Paul, Ltd. She is an excellent example of a handy motor launch, suitable for estuary and river use, and has also been designed so that she may be used for sheltered sea work when required. "Norvic" was exhibited at the 1908 Olympia Marine Motor Exhibition, and attracted a great deal of attention, not only on account of her shapely lines, but also because she was one of the first steel motor hulls to be exhibited at Olympia. The finish of the steel and wood work, both externally and internally, is of the highest class and shows conclusively that, in this respect, steel boats can be made to compare with wooden ones.

The design has been prepared with a view to obtaining as large a floor space aft as possible, it being the owner's intention to substitute basket chairs for the usual side and thwartship seats. The motor, which is a 30h.p. Boulton and Paul four-cycle petrol engine, is fitted as far

forward as possible, but care has been taken to provide ample room around the motor for easy handling and access to all the parts. The motor space is divided off from the passenger space by means of a steel bulkhead.

The scantlings are very much heavier than they would have been had the boat been designed entirely for racing, but although the weight of hull is more than double the weight of a steel racing hull of similar dimensions, "Norvic" has proved quite a speedy little craft, her speed being about 12 knots.

Specification of the Steel Motor Launch "Norvic."

Dimensions.—Length overall 30ft., breadth moulded 6ft., depth moulded amidships 2ft. 10½in.

General description.—The boat to be designed, built and equipped suitable in every respect for use as a pleasure cruising and racing launch. The hull to be well and strongly built of Siemens-Martin mild steel in accordance with this specification and generally in accordance with the plans. The whole of the materials and workmanship throughout to be of first-class quality. The launch to have a straight stem, curved transom stern, large, open cockpit with bulkhead amidships. Motor to be fitted forward of bulkhead, and space aft of bulkhead to be arranged for chairs.

Keel.—Of flat plate type, 14 I.W.G. thick, well riveted to stem. Double keel angles to be fitted, 1in. by 1in. by ⅛in., extending all fore and aft.

Stem.—Of hammered scrap iron, 2½in. by ½in., lower end to be carefully shaped and to extend sufficiently far round the forefoot to form a good connection with the keel.

Frames.—Of angle steel, 1in. by 1in. by ⅛in., spaced 1ft. 3in. apart, and all to extend from keel to gunwale.

Floors.—Of 12, 14, and 16 I.W.G. steel plate, 4in. deep amidships, and to extend straight across from bilge to bilge; to be fitted on every frame, except at forward end of boat, and to be increased in depth at ends as necessary. To be flanged 1in. on top edge and no reverse bars to be fitted, except where shown on plan.

Keelson.—Double keelson angles 1in. by 1in. by ⅛in. to be fitted where shown on plan.

Shell plating.—Of 16 I.W.G. steel plate with lapped edges and butts, single riveted. Transom to be 16 gauge thick, well stiffened with angles as required.

Motor bearers.—To be of steel plate 12 gauge thick, extending as far forward and aft as necessary to distribute the thrust. Lower angles to be 1¼in. by 1¼in. by ⅛in. and to be extended to forward bulkhead. Top angle to be 1¾in. by 1½in. by 3-16in.; ¾in. by ¾in. by ⅛in. stiffeners with brackets to be fitted as required.

Gunwale.—Of steel angle 1¼in. by 1¼in. by ⅛in. extending all fore and aft, and arranged to take a 3in. by 1in. teak rail.

Deck beams.—Of 1½in. by 1¼in. by ⅛in. steel angle on every frame, connected to frames with steel bracket plates. Deck stringer plates and tie plates of 16 gauge thickness to be fitted as shown on plan.

Bulkheads.—Of 18 gauge steel plate well stiffened by ¾in. by ¾in. by ⅛in. steel angles. Forward and after bulkheads to be fitted with doors for access to peaks; doors to be arranged so that they can be screwed up watertight against rubber straps, or as approved.

Decks.—Forward and aft to be of 1in. yellow pine laid in narrow, tapered planks. To be fastened at each beam from below by means of galvanised screws, and to be caulked with cotton and payed with marine glue. Rail of 3in. by 1in. teak to be fitted all fore and aft, forming covering boards at sides of deck.

Motor-casing.—A light casing of teak to be fitted over motor. To have glass skylight top, fitted with brass protection rods and brass hinges.

Flooring.—To be of ¾in. pine, fitted on 2in. by 1½in. pine bearers spaced as shown on plan.

Rudder and steering gear.—Rudder to be of ⅛in. galvanised steel plate with 1⅛in. galvanised wrought iron stock and galvanised tiller; all arranged to be easily portable.

Propeller bracket.—To be of galvanised wrought iron or gunmetal casting with strong palm for attachment to hull.

Coamings.—A coaming of ⅝in. teak to be fitted round cockpit as far aft as 'midship bulkhead. To be 3in. high above deck forward and gradually tapered off to after end. A ⅝in. teak coaming to be fitted across after end of cockpit, and a teak rail across top of 'midship bulkhead as shown on plan.

Mouldings.—A pear-shaped American elm moulding, 2in. by 1½in., to be fitted all fore and aft, but no facing strip to be fitted.

Painting.—The whole of the steel work to receive two priming coats of best red lead paint and two finishing coats of colour to approval. All interior woodwork to be left bright and to receive four coats of best yacht varnish.

Outfit.—One pair brass fairleads forward and one pair aft, one pair brass bollards forward and one pair aft, two ash flagstaffs with brass sockets, one 30lb. galvanised anchor of approved pattern with 20 fathoms 5-16in. galvanised chain, one galvanised chain pipe with flap, set of copper navigating lamps of approved patterns with brass brackets, four manilla becket lines with spliced eyes, one 2½in. manilla warp or painter 10 fathoms long, chairs or seats for after cockpit to owner's approval, two brass spike boathooks, with ash staffs, one long and one short, one brass spike boathook with paddle staff, eight canvas-covered side fenders with white cotton lanyards and brass cleats, one pair ash oars, leathered and copper bound, with one pair gunmetal rowlocks fitted with wooden chocks, cotton lanyards.

4½-Ton Auxiliary Single-Handed Cruiser.

This boat is a good example of the modern type of single-handed cruiser. She has 5ft. 6in. headroom on an extreme draught of only 3ft. 9in, and is an able sea boat, suitable for almost any part of the coast. The addition of a 6h.p. motor makes no difference whatever to her internal accommodation, as the motor is completely installed beneath the cockpit floor, but the presence of a motor enables the owner to make passages that he could not otherwise attempt in calm weather, and also gives him the power to get into small harbours and up narrow waters in the face of a head wind. None of the sailing qualities of the boat have been sacrificed to the motor, but at the same time the power is sufficient to drive the boat at a speed of about six knots under ordinary conditions, and with the propeller blades turned fore and aft in line with the stern post, she would be as fast under sail as any of the regular sailing cruisers of her type. The accommodation consists of a cabin 8ft. in length, with 5ft. 6in. headroom in the centre. The sofa berths on either side are of ample dimensions, with good lockers underneath, and, in addition to these lockers, there are a pair of good-sized sideboard cupboards forward, and a similar pair of smaller dimensions at the after end of each berth. Forward of the cabin is a small fo'c'sle, with room for one folding cot, with a pantry cupboard on the port side, and a separate fore hatch. For single-handed work, the cooking stove and utensils would be fitted on the port side beside this cupboard, and there would be ample room here to stow a large amount of baggage, etc. Aft of the cabin is a good cockpit with watertight floor, a section of which can be removed over the motor. It may appear at first sight that the motor would be rather inaccessible under this floor, but the companion and the large panel in the cabin bulkhead are easily removable, giving access to the motor, and when the section of the flooring above is also removed, the whole of the motor and its gear is exposed. The fuel tank is placed under the side deck on the starboard side, with a fresh-water tank to balance it to port. In addition to these tanks, there is a large amount of locker space under the side decks and cockpit seats, some of which is accessible from the cabin, and the rest from the cockpit. Above the cockpit again is the sail hatch, giving access to the interior of the counter, where there is ample room for all spare sails, warps, etc.

The accompanying specification gives full details as to the substantial way in which the boat is built, from which it will be seen that she is strong enough for the roughest knocking about.

The rig, though not perhaps pleasant to many people, owing to the absence of a bowsprit, has purposely been designed to keep the whole of the sail plan within the extreme limits for the vessel's length, the end of the boom being plumb with the taffrail. This, of course, necessitates a somewhat lofty sail plan. This, however, is not so noticeable when the jackyard topsail is not set. This sail is easily handled, and when not in use is stowed in the fore peak, with the end of the yard lashed under the side deck on the port side of the cabin, being then completely out of the way. Without the topsail, the sail plan is quite snug, and very easy to handle, consisting, as it does, of two sails only, both fitted with roller gear.

In designing this boat, three main qualifications were kept in view; firstly, ease of handling, combined with ample seaworthiness; secondly, comfortable accommodation, combined with small size and light draught; thirdly, good sailing qualities and ample stability.

Several similar boats have proved excellently adapted for this purpose, and a boat of this kind, owing to her small size, is by no means expensive, although the price will largely depend on the class of materials and the simplicity or otherwise of the fittings.

Specification No. 374.
Auxiliary Single-Handed Cruiser.

Dimensions.—Length over all, 27ft.; beam (extreme), 7ft.; draught, 3ft. 9in. All lines drawn to outside of planking. Sections and water-lines spaced as stated on lines drawing.

Scantlings.

Keel.—Oak or English elm; greatest breadth, 2ft.; moulded 4½in.

Stem.—English oak, natural crook, sided 3½in., moulded 4½in. at head, sided 8in. at scarph with keel, to be in one piece if possible, and scarphed and bolted to keel by ⅜in. yellow metal bolts. The lead keel bolts at this spot are to be of ½in diameter yellow metal.

Sternframing.—The counter frame and main stern frame to be in one piece of English oak, as shown in construction plan, the greatest siding being 11½in. at the rudder trunk, tapering to 4in. at the extreme after end of the counter frame. To be sided to suit shape of boat forward of the trunk. The after end of the stern frame (at rudder) to be sided 3¼in. just below rabbet, tapering to 2in. at heel of rabbet. Stern-frame bolting to be as shown by dotted lines. A brass strap is to be fitted around the propeller aperture as shown, to be let in flush with deadwood and through riveted.

Rudder trunk.—Oak, shaped and fitted as shown, with galvanised iron knee to beam at after end, and shown in beam plan.

Rudder.—Of oak. Diameter of stem at head $3\frac{1}{2}$in., tapering to $2\frac{1}{4}$in. at heel. The blade to be tapered to after edge to fair out the run of the boat. The fore edge must be sharpened at propeller aperture. To be fitted with brass straps and pintles, as shown.

Planking.—$\frac{3}{4}$in. finished Kauri pine or other suitable wood in narrow widths.

Timbers.—American elm, moulded 1in., sided $1\frac{3}{8}$in., spaced 7in. centre to centre. The heels of all timbers to be joggled into keel and stem, etc. An extra timber to be worked at mast between the ordinary timbers, to be of same scantling as above.

Transom.—Of oak, teak, elm, or Kauri pine, sawn or steamed to curve, $1\frac{1}{2}$in. thickness.

Beams.—Of pitch pine. The ordinary through beams to be $1\frac{1}{2}$in. sided by $2\frac{1}{4}$in. moulded. Main beams at fore and after ends of cockpit and fore end of cabin top to be of oak, $2\frac{1}{4}$in. sided by 3in. moulded. Other main beams, oak, 2in. sided by $2\frac{1}{2}$in. moulded. Half beams, $1\frac{1}{4}$in. sided by 2in. moulded. All ends dovetailed.

Chocks to be fitted as shown for mast, etc.; to be of hardwood. All main beams to have oak lodging knees and galvanised iron hanging knees.

Rail.—Rail and capping to be of teak, 3in. high at fore end, decreasing in height towards archboard, as shown.

Floors.—Galvanised wrought iron floors, to be fitted at timbers as indicated in letters F, F; to be $1\frac{1}{4}$in. by $\frac{3}{8}$in., tapering towards ends, and to extend well up into the turn of the bilge—swelled for lead keel bolts.

Shelf or gunwale.—American elm or Oregon pine, 2in. sided, 3in. moulded amidships, tapering fore and aft, through fastened through skin and timbers at every alternate timber.

Bilge stringer.—American elm or Oregon pine, $1\frac{3}{4}$in. by 3in. amidships, tapering fore and aft.

Carlines.—Of Oregon pine, $2\frac{1}{2}$in. moulded, 2in. sided, curved fore and aft, as shown.

Cabin top sides and cockpit coamings.—To be of $\frac{3}{4}$in. teak.

Cabin top.—$\frac{3}{4}$in. (canvas covered) white pine on 1in. by 1in. steamed American elm timbers, spaced 8in. centre to centre.

Deck.—$\frac{3}{4}$in. (canvas covered) or $\frac{7}{8}$in. caulked Kauri pine. If caulked, the deck is to be secret-nailed and caulked with cotton and payed with good-quality marine glue.

Breasthook.—Of galvanised iron, $1\frac{3}{4}$in. by $\frac{3}{8}$in. at throat; arms to be 9in. long; size at end of arms to be 1in. by $\frac{1}{4}$in.

Knees.—Lodging knees and quarter knees to be natural oak crooks 1in. thick, shaped as shown.

Cockpit.—To be fitted as shown, with $\frac{7}{8}$in. watertight floor on $1\frac{1}{4}$in. by 2in. pine bearers, spaced as shown. To be fitted with lockers, and space for tanks, as shown.

Bulkheads.—Bulkheads of cabin and cockpit to be of $\frac{5}{8}$in. pitch pine or teak.

Cabin.—The cabin to be fitted up with upholstery, etc., to suit the owner's requirements. The distance between the bulkheads to be 8ft. 1in. Two side-boards are to be fitted at each end of the sofa berth on the port side, as shown, and one side-board only at the after end on the starboard side. Both side-boards at the after end to have lift-up tops.

Four hinged or screw port lights to be fitted on each side and two in the fore end of the cabin top, to be 4in. in the clear and to have brass rims. A portable companion ladder is to be fitted, so that it can be taken away to give access to the motor, and the after bulkhead is to have a movable panel for the same purpose.

Cabin floor and floor beams to be same as for cockpit. Fronts and seats of sofa berths to be $\frac{5}{8}$in. thick pitch pine. Small doors to be fitted in after bulkhead to give access to lockers on each side under the cockpit seats, as shown.

Forecastle.—To be fitted up as shown. The cupboard is to be fitted with shelf and racks for crockery and cooking utensils. The floor in the fo'c'sle to be on the same level as the sofa berths in cabin, as shown.

Sail locker.—A batten-lined sail locker to be fitted aft of the cockpit, with square hatch, as shown.

Deck fittings.—To consist of the following:—One large galvanised iron mooring bollard; one galvanised iron chain pipe; one galvanised iron roller chain lead on side of stem; brass cap to rudder head; one gunmetal fairlead on each quarter; galvanised iron tiller; one galvanised iron pin rail on fore end of cabin top; one main sheet horse; cleats, leads, etc.

Engine.—Engine and tanks to be installed in accordance with engineer's instructions.

Fastenings.—To be of copper and yellow metal throughout. The lead keel bolts to be of yellow metal, $\frac{3}{4}$in. diameter in middle of same, decreasing to $\frac{1}{2}$in. at ends. Wing bolts through wood keel and floors are to be fitted where the width of the keel exceeds 10in. Of same material as above, but $\frac{5}{8}$in. diameter.

Spars.—A complete set of solid, clear-grown Norway spars to be fitted of the following sizes:—Mast, length heel to shoulder, 31ft.; diameter at heel, $3\frac{3}{4}$in.; diameter at deck, $4\frac{3}{4}$in.; diameter at hounds, $4\frac{1}{2}$in.; diameter at shoulder, 3in. Boom, length over all, 19ft. 5in.; diameter at fore end, $3\frac{1}{2}$in.; diameter at after end, $3\frac{3}{4}$in.; to be fitted for roller reefing gear as shown. Gaff, length over all, 11ft. 9in.; length of pin of tumbler to lacing hole, 11ft. 6in.; diameter at jaws, 2in.; diameter in middle, $2\frac{1}{4}$in.; diameter at outer end, $1\frac{1}{2}$in. Topsail yard, length over all, 17ft. 6in.; to be of bamboo, $2\frac{1}{4}$in.-$2\frac{3}{4}$in. diameter. Jackyard, length over all, 9ft. 6in.; to be of bamboo, $1\frac{3}{4}$in. diameter. Foresail roller, bamboo, 20ft. 10in. over all; diameter, 2in.-$2\frac{1}{4}$in.

"White Kitten," Motor Auxiliary Hard-weather Cruiser.

This yacht has been designed and built by Summers and Payne to drawings supplied by her owner, Mr. A. St. George Caulfield. Her owner has built the little yacht for cruising, winter or summer, in the troubled waters of Christchurch Bay, and the passing to and from of the Needles passage. With good beam, full lines and a yawl rig, with a total sail area of 984 square feet, "White Kitten" should suit these requirements. The cockpit is self-draining and not too large. The drawings and specification will give a very comprehensive idea of this little boat.

A feature in "White Kitten" is the installation of the Kelvin motor and Bergius folding propeller. On the Clyde these installations are no novelty, but in the south it is only during the 1908 season this very simple and reliable motor and folding propeller has been introduced.

The motor is a two-cylinder model of 7h.p., and, placed on the starboard side out of the centre line, it occupies very little space; the shafting passes through a hard wood chock and the planking, and is carried outboard by a bracket. When required for sailing, the blades are closed, and offer the minimum of resistance; easily opened, the propeller is working in "solid" water, and the greatest efficiency is obtained. The motor is started on petrol, but the petrol required is only a wineglassful, and is contained in a cup with a screwed top fitted in the cockpit. When this small quantity of petrol is consumed, the motor has sufficiently warmed up to work on paraffin. With the exhaust discharge below water, there is practically no smell, and a speed of five knots can be maintained with absolute regularity.

"White Kitten" has just been built, and is a notable addition to the ever-increasing motor auxiliary fleet of yachts in the South of England.

Specification of a 12-ton Cruising Yawl Yacht.

To be fitted with a 7h.p. Kelvin motor, with magneto, folding propeller, bracket, shafting, petrol tanks, etc., complete.

The yacht to be of about the following dimensions, viz.:—Length (over all) 39ft. 6in., length (L.W.L.) 29ft. 6in., beam (extreme) 10ft. 5in., draught (extreme) 5ft.

To be built at Southampton by Messrs. Summers and Payne, Ltd., to designs and under the superintendence of Arthur E. Payne, A.M.I.N.A., in the best possible manner, and the yacht to be copper or yellow metal fastened throughout.

Keel.—Of English or American rock elm, in one length, sided and moulded as required.

Stern post.—Of English oak.

Stem and deadwoods.—Of English oak, well grown to shape.

Frame.—Of English oak, all grown frames and with a good grain. Frame bolts of copper or yellow metal. Double frames amidships to turn of upper bilge; single frames at each end of yacht, 4in. by 3in. at heel amidships, 2½in. by 2in. at head. To have galvanised wrought iron floors on every frame amidships and on every third frame at ends of yacht, arms of floors fastened with copper bolts clenched on rings. Throats fastened with yellow metal bolts.

Planking.—1⅛in. thick, two top planks each side to be of teak. Pitch pine below that to 2ft. below L.W.L., with American rock elm in bottom. To be fastened with yellow metal dumps and copper through bolts. Shelf of larch, 4in. by 3in., tapered at ends, fastened with yellow metal through bolts clenched on rings.

Deck beams.—Of English oak, 3in. by 2½in., through bolted to shelf and secured with galvanised iron hanging knees and English oak lodging knees, properly fitted and through fastened, with necessary properly-framed mast partners, well fastened.

Decks and plankshear.—Of teak, fastened with yellow metal dowels and edge nails, well caulked with cotton and best Navy oakum, and seams payed with Jeffery's best marine glue. Deck planks to be 3in. by 1⅛in., and laid straight. Bulwark strip of teak, 4in. by 1¼in., well bolted, with clean American rock elm rail on top. Brass mooring chocks on bow and stern.

Skylight, companion and hatch, cockpit coamings and mast bitts of teak.

A properly-constructed lead bilge pump with brass deck plate and galvanised iron pump spear and upper and lower boxes complete; also semi-rotary pump for motor compartment to be supplied.

The inside fittings to be of teak and pine, painted and varnished, as the case may be. Saloon, sofa seats with lockers under, squabs stuffed with hair and covered in pegamoid or other suitable material of any desired colour. One teak folding table and folding wash basin combined and mirror. Net rack at either side above sofas. Two candle lamps, linoleum for floor, teak ladder. One patent underline closet, with all necessary fittings and teak folding top. Pantry fitted with plate racks, shelves, lockers or cupboards, etc.; one lamp. Forecastle fitted with galvanised iron cot frame and canvas bottom, lockers and cupboards, one table, one lamp, one small swing paraffin stove. Linoleum on floor of cockpit.

Rudder.—Oak main piece with blade of English elm or pine, copper rudder bands, with brass pintle at heel. Galvanised iron or wood. Tiller, brass cap for rudder head.

Spars to consist of pole mast, boom, gaff, topsail yard, jack yard, bowsprit, mizzen mast,

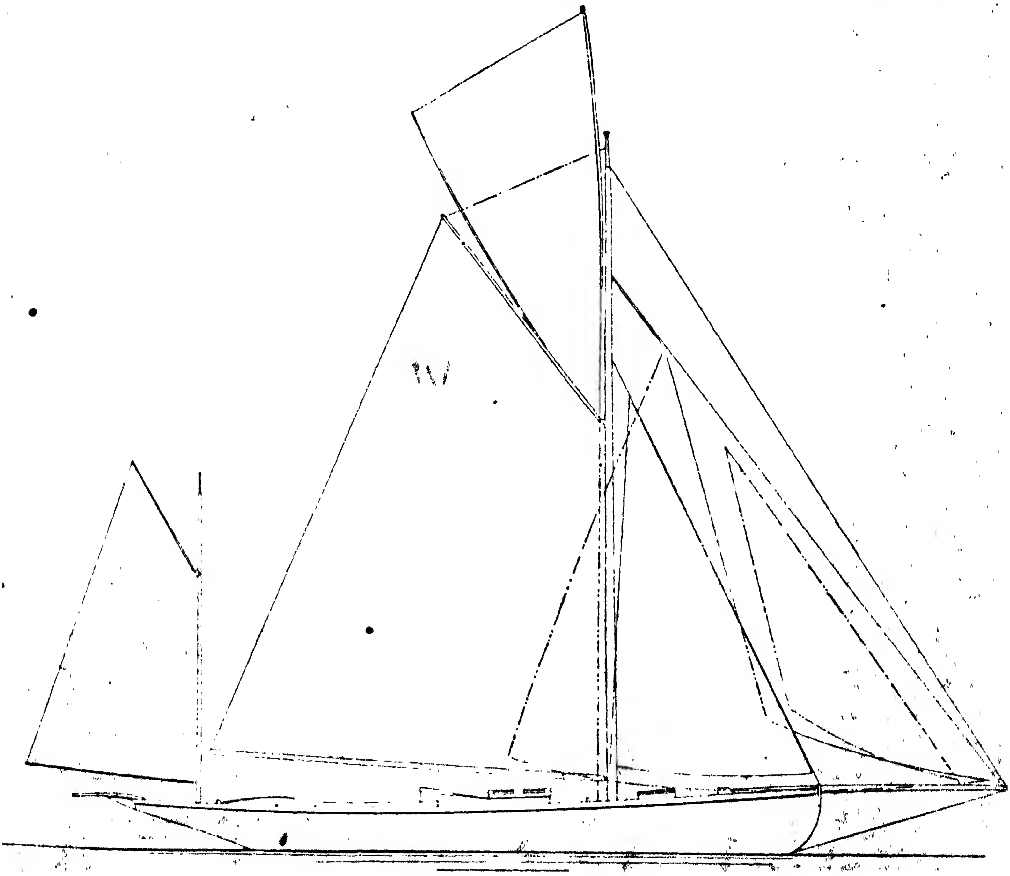
boom and gaff, outrigger. All spars solid, except topsail yard, which is to be hollow. Sails (tanned) to consist of one main sail, one fore sail, one mizzen, one jackyard topsail, one balloon jib topsail, two jibs, one balloon foresail and sail coats.

A suitable small capstan and bollards to be fitted, with roller on stem for cable. One galvanised bower anchor, one galvanised kedge anchor, 45 fathoms galvanised short link $\frac{3}{8}$in. chain cable, one warp, one hand lead and line, two spare tackles.

Rigging.—All necessary galvanised steel wire standing rigging for rig; all necessary running rigging of best hemp and manilla yacht rope, and rigging screws. A complete set of blocks suitable for a yacht of this size, to have extra thick sheaves to allow the rope to run freely, and all to be patent sheaves. All necessary ironwork for yacht, blocks and spars to be of the best make and properly galvanised and leathered where required.

Other fittings.—Galvanised iron man rope, stanchions, cotton man ropes, side ladder, binnacle and spirit compass, one lifebuoy, one galvanised bucket, side lamps and boards, masthead lamp, one riding lamp (japanned). Ballast, lead, about four tons on keel with sufficient inside lead ballast to trim yacht to her designed water line. The yacht to be properly prepared and painted, or varnished, as the case may be, inside and outside. The hull outside to be painted three coats and one coat of enamel on topsides, and gold line round yacht. The bottom to have three coats of approved anti-fouling composition.

The whole of the materials used in the construction of the yacht and her outfit to be of the best of their respective kinds, and of first-class workmanship, and to be completed ready for sea, excepting plate, crockery, glass, linen, owner's blankets, bedding and consumable stores, and delivered off the yard, after satisfactory trial run with power and under sail.



Sail Plan of "White Kitten."

"Concara," Motor Auxiliary Fishing Yacht.

We will turn for the moment from new boats to an old and well-tried fishing yacht, "Concara."

This little vessel, designed and built in 1904 by Summers and Payne, specification and plans of which follow, has proved a very reliable and serviceable type of yacht, and notwithstanding the exceptionally large well which her owner had made to his own requirements and to suit his trawl as well as line fishing on the Devonshire coast, "Concara" has proved a good sea boat. Snugly rigged as a pole-masted cutter, with a sail area of 1,187 square feet, she is not fast in light airs (this is not required, however, as the motor then comes into use), but in moderate to hard winds she shows good speed and is well balanced.

The motor is a two-cylinder Thornycroft, with cylinders 6in. diameter by 8in. stroke, and developing 24b.h.p. at 700 revolutions. The speed obtained is 6.75 knots.

The propeller is two-bladed, and, when sailing, is covered by the stern post, offering but small resistance.

The Hele-Shaw reversing gear makes the control for the helmsman very simple, and has worked extremely well.

A power capstan is a feature in this well-equipped fishing yacht, and for working the trawl beam or getting up the anchors, saves a great deal of labour. Power is transmitted from the main engines by shafting and bevel gear. To take the shock of breaking out an anchor, or undue strain from the trawl, a slipping clutch is provided, and the capstan has proved in the four years of its existence a success.

The accommodation was designed to suit the owner's requirements. "Concara" was to be used as a "day boat," but comfortable quarters are provided in the event of the owner and a friend wishing to stay out for a night.

The main cabin has sofa berths 6ft. 6in. long, and wide enough to sleep with comfort. Sideboards and lockers are provided for the provisions, and adjoining is a well-fitted pantry. There is a good roomy closet and lavatory, and a forecastle which will accommodate two paid hands, in case an "extra" hand is required.

The specification will show what a strongly-built vessel "Concara" is; her teak planking and oak frame and finish throughout are almost unnecessarily good for the work such a yacht is designed for.

Specification of the Auxiliary Motor Fishing Yacht "Concara," of 16 Tons T.M.

Dimensions.—Length on l.w.l., 35ft. 6in.; beam extreme, 10ft. 7in.; draught, 6ft.

Scantling, etc.—Keel.—Of English elm, and 7in. deep.

Stem.—Of English oak, 5in. sided, and moulded as required, to be well grown to shape.

Stern post.—Of English oak, 5in. sided.

Deadwoods.—Of English oak and elm, as directed by the architect, and to be well fastened with yellow metal bolts, ½in. and ⅝in. in meter.

Rudder.—Mainpiece of English oak, 5in head, blade of rudder to be of pine, well faste with ½in. yellow metal bolts.

Frame.—Of English oak, all well grown shape, and free from sap and other defec Sided 2¼in. and moulded at keel 4in., tapering 2½in. at head.

Planking.—Of teak, 1⅜in. thick, from she strake to water line, below that of pitch pine, with garboards of American rock elm, 1⅜in. thick.

Deck.—Of best-selected yellow pine, 1½in. thick, planks to taper fore and aft, and to be in as long lengths as possible, and free from knots and shakes, fastened with dowels and diagonal edge nails, the seams to be very carefully caulked with cotton-wool and best oakum, and payed with Jeffery's first quality marine glue.

Covering board.—Of teak, 1⅜in. thick, to be well fastened with metal screws.

Deck beams.—Of English oak, sided 3¼in. and moulded 3⅜in.; mast beams, 4½in. by 3½in.

Knees.—To have 10 wrought-iron hanging knees aside, as directed by the architect, to be fastened with copper bolts, three in each arm. Five oak lodging knees to be fitted on each side, where required.

Clamp.—Of teak, 4in. thick and 6in. deep, through fastened with copper bolts.

Bilge stringer.—Pitch pine, 6in. by 1½in., to be worked on either side, through fastened with ⅜in. copper bolts.

Rails.—Of clean American elm, to be well seasoned and free from defects.

Bowsprit bitts.—Of galvanised steel.

Capstan.—A capstan of suitable size, with the usual stoppers and compressor, as supplied by Messrs. Percy Thellusson and Co.

Caulking.—The yacht to be very carefully caulked with best oakum, and the seams payed and puttied, as directed.

Ballast.—A lead keel of about 4½ tons, to be cast and fitted, and securely fastened with copper and yellow metal bolts and nuts, as directed by the architect; sufficient internal lead ballast to float vessel to designed l.w.l.

Steering gear.—Galvanised iron tiller.

Fastenings.—To be of copper and metal throughout. The planking to be fastened with ⅜in. metal dumps and 5-16in. copper bolts in butts, deadwood bolts to be of ½in. and ⅝in. copper and metal. Lead keel bolts of 1⅛in. copper and metal, hove up with nuts.

Iron floors.—Wrought-iron floors to be fitted to every frame amidships and alternate frame at ends, and to be through fastened with copper bolts, through frames and not through outside planking.

Deck work.—All skylights, companion ways, and hatches to be of teak, very neatly fitted.

Internal fittings.—To be of teak and pine, very neatly fitted, and arranged according to plan. Forecastle to be bright varnished, painted or grained, and to have galvanised iron cots.

Caboose.—An oil stove of good make to be supplied and fitted with all necessary utensils suitable for size of vessel.

Pump.—One properly-constructed pump to be fitted to bilge, to discharge through ship's side under water.

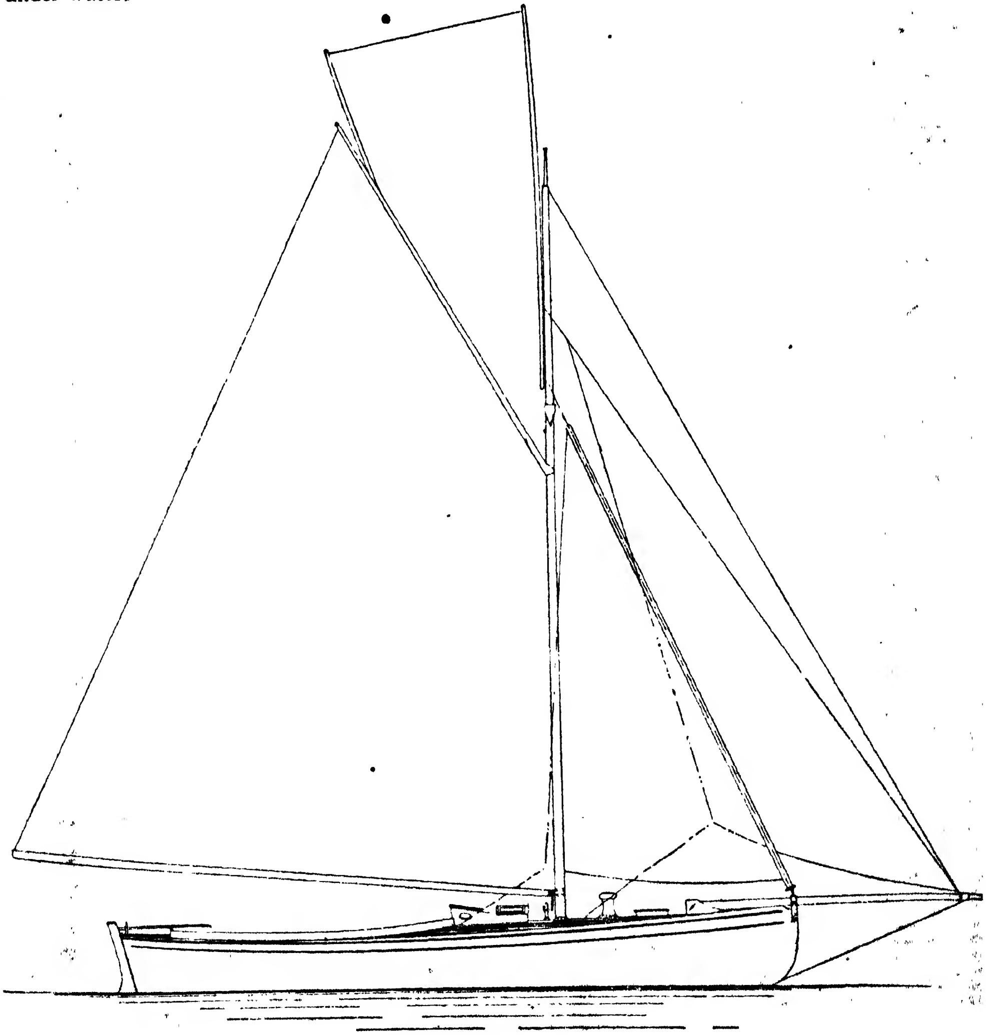
Deck fittings.—All deck fittings of approved make to be supplied and fitted as is usual in a yacht of this size.

Bobstay, bar, etc.—To be of copper and gun-metal.

Ridge rope stanchions.—To have ridge rope stanchions of galvanised iron fitted on each quarter, with quarter cloths properly fitted.

Mooring cleats.—To have two brass mooring cleats on taffrail and two on the fore end of rail.

Spars.—To have a complete set of spars suitable for the rig. The mast to be of pitch pine; all to have the necessary galvanised iron fittings of best make.



Sail Plan of "Concara."

Blocks.—To have a complete set of best internal-stroped ash blocks, with patent roller sheaves to halliards and main sheet.

Standing rigging.—To be of best steel wire of suitable size and neatly fitted.

Running rigging.—To be of best hemp and manilla and steel flexible wire rope. All to be fitted to the satisfaction of the owner or his captain.

Sails.—A complete suit of sails by Ratsey and Lapthorn, consisting of mainsail, roller foresail, three jibs, one topsail, one spinnaker, one jib-headed trysail, with all necessary sail coats and bags.

Anchors and cable.—To have one galvanised bower anchor and one galvanised kedge anchor, and 45 fathoms of galvanised chain cable. One warp and two suitable hauling lines.

Upholstery, etc.—The upholstery to consist of linoleum on floor of cabin and closet, cushion of cabin of hair covered in selected leather.

Binnacle.—A binnacle of brass, with liquid compass of best make.

Winch.—A patent Gipsey winch, to be fitted to mast, all galvanised.

Lamps.—A pair of copper dioptric side lamps, with screens complete, a copper riding lamp, and bronzed cabin lamp, to be fitted to saloon, and two candle lamps, to be fitted where required. One bulkhead paraffin lamp for forecastle.

Bell, etc.—A bell and fog-horn and flareup, as required by the Board of Trade. Also the necessary hand leadlines.

Painting.—The outside of the yacht to have four coats of best oil paint, the topsides to be finished bright varnished, the inside to be neatly painted, varnished, and polished, as desired. The deck work to receive four coats of best copal varnish.

Boats.—A suitable dinghy built of pine and teak fittings, and fitted complete with oars, crutches, boathooks, etc. Boat 12ft. long and bright varnished.

Forecastle requisites.—The usual dustpan, hair broom, banister brush, wash kids, basin, lamp, mirror, plates, cups, knives and forks, spoons, etc., for use of crew.

Sundries.—Two water breakers, four cork fenders, two lifebuoys, one canvas bucket, two cork deck cushions, one squeegee, two coir brooms, two hair paint scrubbers, one mop, two chamois leathers, etc., stand for water breakers.

The yacht is fitted with a Messrs. John I. Thornycroft and Co., Limited, two-cylinder motor. Diameter of cylinders 6in. by 8in. stroke, and 26b.h.p.

A Cruiser With Auxiliary Sails.

"Nornodeste," which was designed by Mr. James A. Smith, M.I.N.A., is built of teak, with oak and elm timbers, elm keel, etc., oak stem, stern post, etc., and has a heavy outer keel of iron. She is 14 tons Y.M., and measures 42ft. long over all by 9ft. beam, and is fitted with a 30h.p. Gardner paraffin motor, with Gardner reverse gear, clutch and thrust. The motor is installed in the forecastle, and the accommodation, consisting of a large saloon and double-berthed state-room, with the usual offices, is thus kept all together and away from the machinery. The speed obtained during the preliminary trial was just under nine knots, being fully half a knot in excess of the estimated speed, which shows that the novel type of yacht selected by the designer is quite satisfactory as regards speed. Her sea-going qualities also are all that could be desired. "Nornodeste" is being fitted with an auxiliary schooner rig consisting of two pole masts with Bembridge lugs, and there is sufficient sail area to enable the yacht to be manœuvred without the use of motor power. The aim of the designer in this case has been to produce a motor boat of a thoroughly seagoing type, with comfortable cruising accommodation, at a minimum cost, and the preliminary sea trials of "Nornodeste" showed that the object has been attained.

Specification of "Nornodeste"

Dimensions.—Length over all 41ft. 11in., breadth (extreme over planking at deck) 9ft., draught (maximum) 3ft. 5in.

General description.—The vessel to be strongly constructed of wood in accordance with the plans and this specification. To be completely decked over, with the exception of a small cockpit aft, and the sides of the boat to be carried up to form the cabin. To be schooner rigged with Bembridge lugs and staysail. The vessel to be delivered complete in seagoing order after satisfactory trials under motor and sails. The whole of the workmanship and materials to be of the best quality, and the work to be done under the supervision of the owner or his representative.

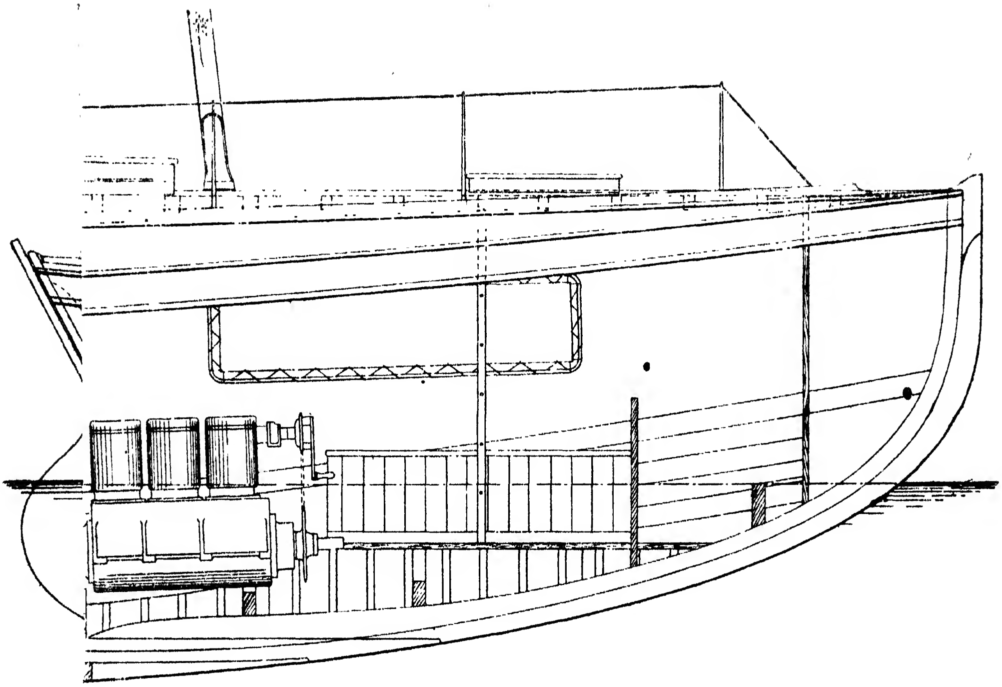
Keel.—Of English elm, 4½in. thick, and shaped to form of boat as shown on plan. After end to be tenoned into stern post.

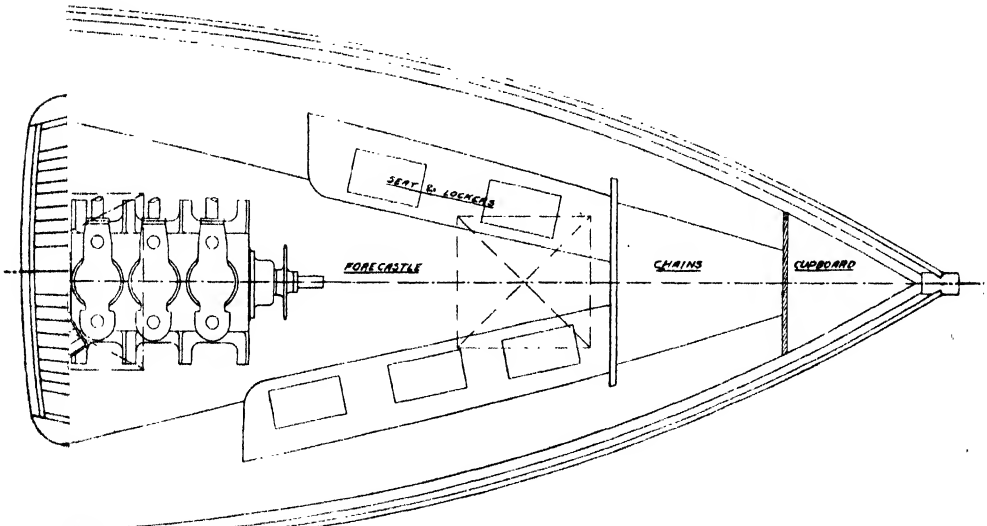
Stem.—To be of English oak, grown crook, 6in. moulded and 4in. sided. To extend over keel as shown on plan, and to be securely bolted to keel with ½in. copper bolts. Upper end to be left square and the rabbet cut so that the stem follows out the lines of the boat. If the stem cannot be obtained in one piece, it may be put in in two pieces with a long scarph, with a strong apron piece inside.

Transom.—Of 1½in. English elm with a 4in. grown oak crook knee inside.

Stern post.—Of English oak, sided sufficiently to allow plenty of substance at stern tube. Lower end to be tenoned into keel, and the top to extend through the counter frame to the inside of the boat.

Deadwood.—To be in two pieces as shown on plan, and to be of sufficient thickness for





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shaping, so as to carry out the lines of the boat. A short counter frame to be fitted from transom to stern post, and rabbeted to receive planking. The whole of the deadwood, stern post and keel to be strongly fastened together with copper bolts.

Timbers.—Of $1\frac{3}{8}$in. by $1\frac{1}{8}$in. American elm, spaced 7in. centres. Lower ends to be joggled into keel, and all timbers to extend to the deck in the cabins.

Planking.—Of $\frac{7}{8}$in. finished pine, fitted carvel fashion with caulked joints. Planks to be fitted in narrow widths with as few scarphs as possible. The wood is to be free from sap and large knots. Seams to be caulked with cotton and stopped with white lead putty. Cabin sides above sheer line to be of teak in one width, and to be finished bright.

Shelf.—Of $4\frac{1}{2}$in. by 2in. Oregon pine, from stem to after end of cabin top. Another shelf to extend from transom forward to about section 5 at line of sheer. To be fastened through planking and timbers with stout copper nails clenched over rooves.

Bilge stringers.—Of 4in. by 2in. Oregon pine in one length each side. To be fastened at every second timber with stout copper nails, and to have an oak breasthook forward and oak knees aft.

Beams.—Of $2\frac{1}{2}$in. by 2in. pine. Beams at after end of cabin and two beams under each mast to be of 3in. by $2\frac{1}{2}$in. oak. Ends of beams to be dovetailed into shelf and to have about six strong galvanised iron hanging knees and six oak lodging knees each side.

Deck.—Of 1in. yellow pine, free from knots, shakes, sap and other defects, laid in narrow planks, with seams caulked with cotton and payed with marine glue. A covering board of teak about 5in. wide to be worked round edge of deck.

Coamings.—Coamings round cockpit to be of 1in. teak, standing 4in. high above deck. To have teak corner knees and a teak moulding round upper edge.

Floors.—Of 3in. oak crooks, with arms extending well up bilges. Floors at ends of boat to be of $2\frac{1}{2}$in. and 2in. oak as necessary. To be through fastened wherever possible and floors which do not carry keel bolts to have $\frac{1}{2}$in. copper bolts through the middle.

Motor bearers.—Fitted as necessary, of 3in. oak. To be arranged to distribute weight and vibration over as large a length as possible, and to be firmly fastened through floors and timbers with copper bolts.

Bulkheads.—Bulkheads at forward and after ends of cockpit to be of teak. All others of pine. To be strongly fastened to sides of boat to assist in the transverse strength. To be of matching 4in. wide, with tongued and grooved joints and V'd edges. To be fitted with necessary doors with brass furniture.

Flooring.—Of $\frac{7}{8}$in. pine, laid on $2\frac{1}{8}$in. by $1\frac{1}{2}$in. pine bearers, spaced about 15in. apart. Flooring in cabin to be covered with linoleum of approved pattern and quality.

Mouldings.—A pear-shaped moulding of elm, 2in. by $1\frac{1}{4}$in., to be fitted round boat at sheer line, and a lower moulding of $1\frac{1}{4}$in. by $\frac{3}{4}$in. elm to be fitted under top strake. Covering board round raised deck to project beyond planking to form a moulding. Small quarter moulding to be fitted round coamings.

Cabin work.—All necessary bunks, lockers, cupboards, shelves and other fittings, including w.c., to be supplied and completed to owner's requirements. Fittings in motor room and forecastle to be of pine.

Hatches and skylights.—A teak sliding hatch to be fitted at after end of deck for access to cabin, and another sliding hatch to be fitted aft of foremast if required. Teak forecastle hatch to be fitted. Two teak skylights with brass hinges, quadrants and protection rods to be fitted.

Rudder.—Of 3-16in. galvanised steel plate with $1\frac{1}{2}$in. galvanised post. Lower end of post to have a bearing on end of keel and two straps bolted through transom to carry upper part of post. Top of post to be squared and a galvanised iron tiller to be fitted. A steering wheel to be fixed on after side of cabin bulkhead and connected to tiller with steel wire leads over galvanised sheaves.

Rail.—Light galvanised stanchions to be fitted round raised deck standing about 1ft. 9in. high. Lower ends palmed and bolted through covering board and shelf. Rail to be of $\frac{3}{4}$in. galvanised steel rope. Small teak rail 2in. high by $1\frac{1}{4}$in. thick to be fitted at sides of deck all fore and aft.

Iron keel.—Of about one ton in weight, and shaped as shown on plan, to be supplied. To be fastened to boat with $\frac{3}{4}$in. galvanised iron bolts, set up with nuts inside. Filling pieces of English elm to be fitted at forward and after ends of iron keel as shown on plan.

Ballast.—About 20cwt. of iron ballast in conveniently shaped pieces to be supplied.

Fastenings.—All to be of copper or brass, except keel bolts, and to be sufficient in number and strength.

Spars.—Masts to be of spruce of length as shown on plan, about 4in. diameter at deck. To be stepped into tabernacles of galvanised iron, arranged to allow mast to be lowered. Yards and sprits to be of spruce of suitable dimensions.

Rigging.—Consisting of forestay and two shrouds each side to foremast, and two forestays and two shrouds each side to mainmast, of best galvanised steel wire rope. Shrouds to be set up to galvanised chain plates with rope lanyards, and forestays to have tackles for lowering the masts. Running rigging of best yacht manilla as required, with best ash blocks. Mast hoops of ash and jaws or travellers for yards to be fitted.

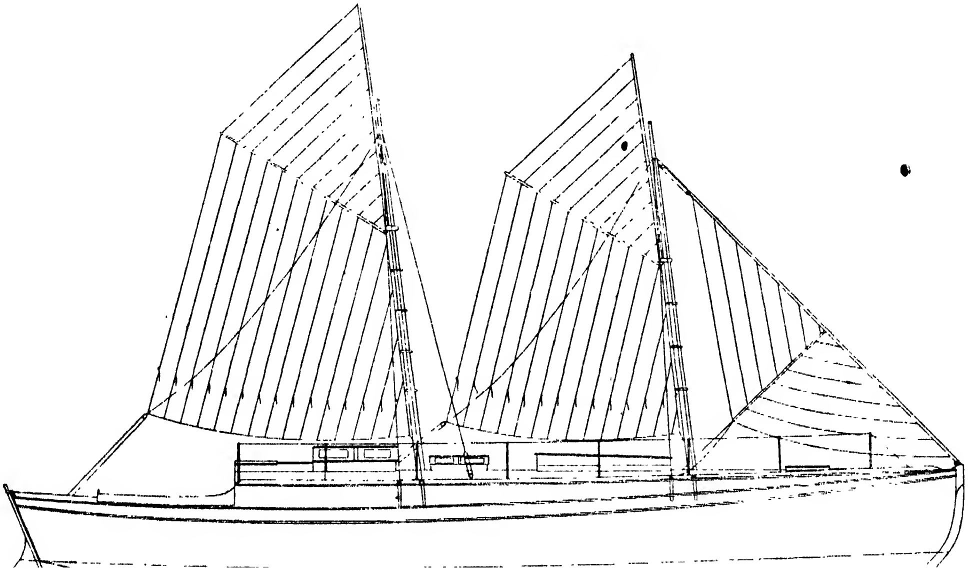
Sails.—To be by an approved maker. Of

best cotton duck with all necessary thimbles, reef points, hanks, sail covers, etc.

Iron work.—All iron work for deck fittings and spars to be of best quality and thoroughly galvanised.

Finishing.—Outside of boat to be thoroughly smoothed down with glasspaper, and painted with three coats best oil paint, finished with two coats of enamel of approved colour. Bottom of boat to have two coats of anti-fouling composition. Inside of boat below floor boards to have four coats best oil paint. All bright work outside and in cabins to have four coats best yacht varnish. Spars to have three coats best yacht varnish.

Outfit.—Galvanised roller fairlead on starboard side of stem head and galvanised fairlead on port side; large mooring bollard forward; two fairleads aft; all necessary cleats, belaying pins, and leads for sheets; small windlass of approved pattern; 45lb. galvanised anchor of approved pattern; 20 fathoms ⅜in. galvanised chain; 15 fathoms manilla warp; large ash boathook.



Sail Plan of "Nornodeste."

82ft. Twin-screw Motor Yacht.

The appearance of this vessel to some extent suggests a small and able cruiser or despatch boat, owing to her ram bow and typical man-o'-war stern. These features, however, were adopted with a view to her use in canals and inland waters of Holland and Belgium, as the vessel was designed for a well-known Belgian yachtsman. The ram bow and sharp stern, which give the greatest length over all at or about the water line, were adopted with the object of protecting the vessel when in a lock, as these locks are often very crowded with heavy barges and other commercial vessels, which, when entering, are not too particular as to whether they hit another vessel or not. The slight ram bow will, therefore, take any collision forward with other vessels or lock gates at a point where it is extremely strong, and the same remarks apply to the stern. In both cases any collision that might occur in this way will leave all the ornamental and comparatively flimsy upper works untouched, taking the force of the blow on the main body of the boat.

The draught of 5ft. for a vessel of her size is, of course, very light, but this is necessary for the waters for which she is designed. At the same time, she has good stability, owing to her flat bottom, and is quite capable of any ordinary coast cruising in weather suitable for an ordinary steam yacht of her tonnage.

Extreme speed has not been attempted in this vessel, her power being two 30h.p. Dan engines, which will give the vessel a speed of about eight knots. As these engines have only two cylinders each, the engine-room is naturally very short, although there is ample room for the engineers and complete accessibility to all parts of the machinery. The total length of the engine-room is only 10ft., but extends for the full width of the vessel, with ample fuel tanks at each side.

The crew are berthed aft, and have very good

accommodation under a low, raised cabin top, which extends right aft from the engine-room. There are berths for six men, with a good mess-room, having locker seats all round, in addition to which there is a separate lavatory for the crew. The other accommodation aft of the engine-room consists of a two-berth state-room on the starboard side, and a slightly smaller single berth state-room to port, with a lavatory and oilskin locker alongside the companion. These state-rooms are under the same cabin top as the crew's quarters.

Forward of the engine-room, and under the deck-house, is a large double-berth state-room for the owner, entered from a short passage companion out of the saloon. On the port side is a large bathroom, lavatory, and wardrobe. Next comes the saloon, extending the full width of the vessel, for a length of 10ft. It is fitted with ample seating accommodation and a large sideboard on the port side forward, with a sofa alongside the companion on the starboard side aft, and ample locker space. A door from the saloon leads into the ladies' cabin right forward, which is fitted with three berths, two wardrobes, washstand, and dressing table, and a lavatory between this cabin and the forward collision bulkhead. In addition to this accommodation, there is a good-sized deck-house, with galley and oilskin locker aft, and a deck saloon forward. The deck saloon is entered by means of a semi-open shelter under the bridge deck, fitted with seats on either side, but no doors, the side entrances being open to deck. The deck saloon is fitted with table and seating accommodation for 6-7 persons, with sideboards, lockers, and cupboards, and leading from it is the companion-way into the main saloon.

It will be seen that the vessel is fitted with a small schooner rig similar to that usually adopted on small steam yachts. She carries two boats in davits aft, an 18ft. motor launch on the starboard side and a 14ft. dinghy on the port side. The engine-room is under a raised steel engine-house, with the usual skylights and large ventilators. On this is a platform for the helmsman, fitted with steering wheel, binnacle, and engine-room telegraph, and on the port side of this a ladder leads to a small promenade deck on the top of the deck-house. The low cabin top aft forms a convenient seat all round the after deck, and the top of it forms a roomy deck. Forward of the deckhouse there is a large skylight, part of which is over the saloon and part over the ladies' cabin, while forward there is a powerful hand capstan. The masts are made to lower for passage under the numerous bridges on the canals.

Altogether, the vessel shows unusual accommodation for a boat of her size, and should be very suitable for Dutch and Belgian waters, or for use on the French canals.

It may be well to mention that her owner is very fond of winter cruises for the purpose of wild-fowling, and the deck of the after cabin top is well suited for stowing one or two cunning punts.

She will be built of steel, in accordance with the accompanying specification, with all the deck-house work, skylights, etc., in teak. For British waters there would be no object in having the modified ram bow, and for our coasts—where heavier weather is likely to be encountered—it would be probably advisable to increase the draught to 6ft.

Specification No. 398.
Steel Motor Yacht.

Principal dimensions.—Length over all, 82ft.; beam, 16ft. 6in.; depth moulded, 8ft. 6in.; draught, extreme, 5ft. 6in.

Keel.—Of plate, 2ft. 6in. by 3-16in.

Stem.—Of plate, 4¾in. by ⅝in.

Frames.—To be 2in. by 2in. by ¼in., spaced 20in. apart.

Reverse frames.—To be 1¾in. by 1¾in. by 3-16in. along top of floors. To extend to gunwale, in way of machinery.

Beams.—To be 3in. by 2½in. by ¼in. on alternate frames.

Floors.—To be 12in. by ¼in., straight on top.

Outside plating.—Sheer strake and keel to be 3-16in., the remainder to be ⅛in.

Deck.—Deck stringer to be 15in. by 3-16in. widened in way of machinery hatch.

Riveting.—All butts to have double-riveted straps in the inside. Laps to be single riveted.

Gunwale.—To be of angle bar, 2½in. by 2in. by ¼in.

Bulkheads.—Plating to be ⅛in. thick and stiffened with angles 2in. by 2in. by 3-16in., spaced 30in. apart.

Keelson.—An intercostal plate centre keelson to be fitted and connected to heel plate by double angles, 2in. by 2in. by ¼in., with continuous angles of similar section on top of floors, and connected to the reverse frames and floor by a lug.

Coamings.—Round engine hatch to be plate, 2ft. by ⅛in.

Steering gear.—Hand steering gear, with teak wheel, brass bound.

Capstan.—Hand capstan to be supplied.

Anchor and chains.—One 1½cwt. stockless anchor and 30 fathoms of chain.

Bollards.—To be of galvanised cast iron.

Painting.—Vessel to be coated with three coats of best oil paint.

Woodwork.—Deck to be covered with Kauri pine 1¾in. thick. Cabin floors to be of yellow pine 1½in. thick. Deck-house of teak 1in. thick. The whole of the cabins to be panelled in pine, the sides to be lined half-way up, and any exposed steelwork to be cork-cemented and painted. The whole of the woodwork to be enamelled white.

Deck-house and companion.—To be of teak.

Skylights.—Of teak.

Stanchions and handrails.—Of galvanised iron.

Upholstery.—An imitation leather of approved make.

Scuttles.—To be brass bound.

Outfit.—A complete outfit of ropes, mops, scrubbers, etc.

Stern tube.—Iron stern tube to be supplied by the builder.

Telegraph.—A telegraph of the reply pattern to be supplied.

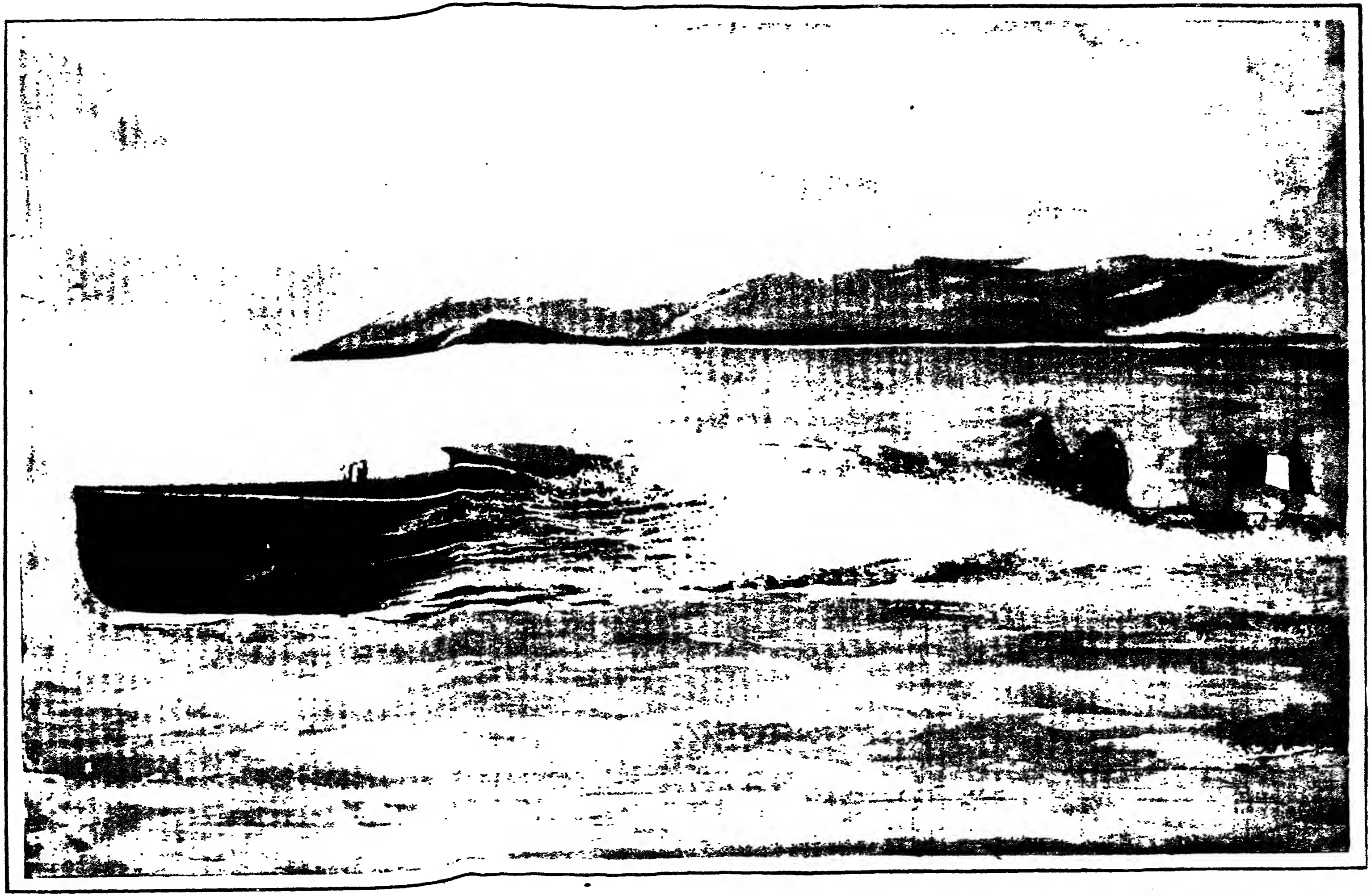
Mast and sails.—As shown.

Lavatories.—Lavatories, w.c.'s, folding basins, cupboards, all as per plan.

Delivery.—The vessel to be delivered afloat and ready for sea, Port of London.

Boats and awnings.—No boats or awnings are included in this specification and estimate, but will be supplied as extras to suit owner's requirements.

"Irene II.," the American Motor Yacht that won the Long-distance Race in 1908.



"Panhard-Levassor," Champion of the Sea for 1908. She was a Tellier 50ft. boat, and, engined with four 100h.p. Panhard motors, her speed was 30 knots.

THE BUILDING OF MOTOR BOATS.

The preceding article on general principles of construction is intended to enable those interested in the subject to acquire a good general knowledge of the proper materials and proportionate scantlings, together with the different methods of construction employed for each style of boat.

The present article has for its object the endeavour to explain, so far as is practicable on paper, the actual method of building a motor boat. It is of course impossible to give instructions for all classes of craft, but the craftsman who has successfully and creditably built a boat on the lines about to be described will no doubt be able to construct others to elaborated designs without great difficulty. We have no desire to touch upon any of the rudiments of carpentering or of ordinary boat building, and the possession of skill and a certain amount of knowledge and experience will therefore be presumed in dealing with the subject; but we will just mention two most important items which are essential to success and which are often overlooked, especially by the inexperienced, namely :—

Accuracy in Measurement.—Every measurement must be taken with the greatest care and be checked over to avoid any possibility of a mistake; nor can one be too particular in plumbing, levelling, and squaring the moulds, etc., when setting up the boat in frame.

Care of Tools.—All cutting tools for wood must be kept properly ground to an angle of about 30deg., and with a keen edge. Tools must never be allowed to get blunt, or the cutting angle get too steep through trying to keep them sharp on the oilstone when they really want grinding.

Explanation of Design Drawings.

Before describing the process of laying off the proposed boat to full size from the small scale of the design, we will give a short explanation of the meaning of the lines as shown in the design, and, although this will doubtless appear rather superfluous to those of our readers who are professional builders, and, therefore, are accustomed to this work, it may be of great assistance to those who have not worked from a design, but would like to do so. In some cases, even builders who have proved themselves capable of turning out the highest class of work on these small craft, are not accustomed to laying off their boats from the drawings, although they may be first-class workmen, but require a full-sized body plan from the designer of the boat before commencing to build. A complete set of lines, or the design, of a vessel of any sort consists of three drawings, viz. :—(1) The profile drawing; (2) the half-breadth plan; and (3) the body plan.

Sheer Plan.

The first, or side elevation, which is known as the *sheer plan*, shows the vessel as seen from the right-hand or starboard side with her bow to the spectator's right: this drawing gives all vertical heights above the load water-line and below it, it shows the curve of the sheer or deck line of the boat, and also the outline of the stem, keel, and stern both above and below water. This drawing also shows the curve of the buttock lines, or vertical longitudinal sections parallel to the keel.

Half-breadth Plan.

The *half-breadth plan* is a plan or bird's-eye view of half the vessel as she would appear if turned bottom up, it shows the deck line (which was also the sheer line in the first drawing), load water-line, or line on which the vessel is intended to float, and all other longitudinal *horizontal* sections that may be necessary. A similar half-breadth drawing of the deck arrangement is usually given, as seen when the boat is right side up, but in many cases, as this consists solely of the position of the motor and seats in the cockpit, etc., it is shown either dotted over the half-breadth plan proper, or else it is made a part of the construction drawings, which should give details of all the various fittings as well.

Body Plan.

The third, and perhaps (from the builder's point of view) the most important, drawing of the set is the body plan, which shows all the cross sections from which the moulds for building must be made. In this drawing, which is really a half elevation of the forward and after halves of the vessel, the sections forming the fore body of the boat are placed to the right of a vertical centre line, while the after sections are shown on the left. On this drawing the load water-line (L.W.L.) and all the other water-line or horizontal sections are shown as horizontal lines, and the buttock lines are shown as vertical lines parallel to the vertical centre line of the vessel. The diagonals, if used, also show as straight lines here. The only lines showing as curves on the half-breadth

plan are the water-lines and sheer line. On the half-breadth plan, the cross-sections and buttock-lines show as straight lines, at right angles to and parallel respectively to the longitudinal centre line. The deck-line, load water-line, and other horizontal sections show on this drawing with their proper curve and shape. In the sheer plan, the cross-sections, load water-line, and all longitudinal horizontal sections (known as water-lines) show as vertical, or horizontal straight lines.

Diagonals.

The diagonals are sections taken parallel with the length of the vessel, but neither vertical nor horizontal, being at such an angle with the buttocks and water-lines as to cut the cross-sections at an angle between the two, so that, where the curve of the section is somewhere about 45 degrees with the water-lines and buttocks, the diagonal will cut it more nearly at right angles than either of the others would do, thus ensuring greater accuracy in the fairing up of the design.

Construction Drawings.

The construction drawings, as will have been apparent in the various examples given in the article on general principles of construction, generally consist of a similar set of three drawings to the lines; but, in this case, the place of the sheer plan is taken by a vertical longitudinal section through the fore and aft centre line of the vessel. This section shows the moulded sizes or depths of stem, keel, stern frame, floors, and engine bearers, together with all internal details of construction and fittings.

Instead of the half-breadth plan, a similar drawing may be given of the internal fittings and plan of the motor with its bearers, etc., and all details of the cabin plan, if there should be one. One or more cross-sections are also given, showing details of the framing and construction of the hull, such as the sectional form and size of the keel, stringers, gunwales, and engine bearers, and, in addition to this, full particulars are given of the method of fixing the motor and any cabin fittings where these exist.

In special cases, where ordinary practice is to be departed from in any of the parts of the framing or fittings, it is usual to give a large

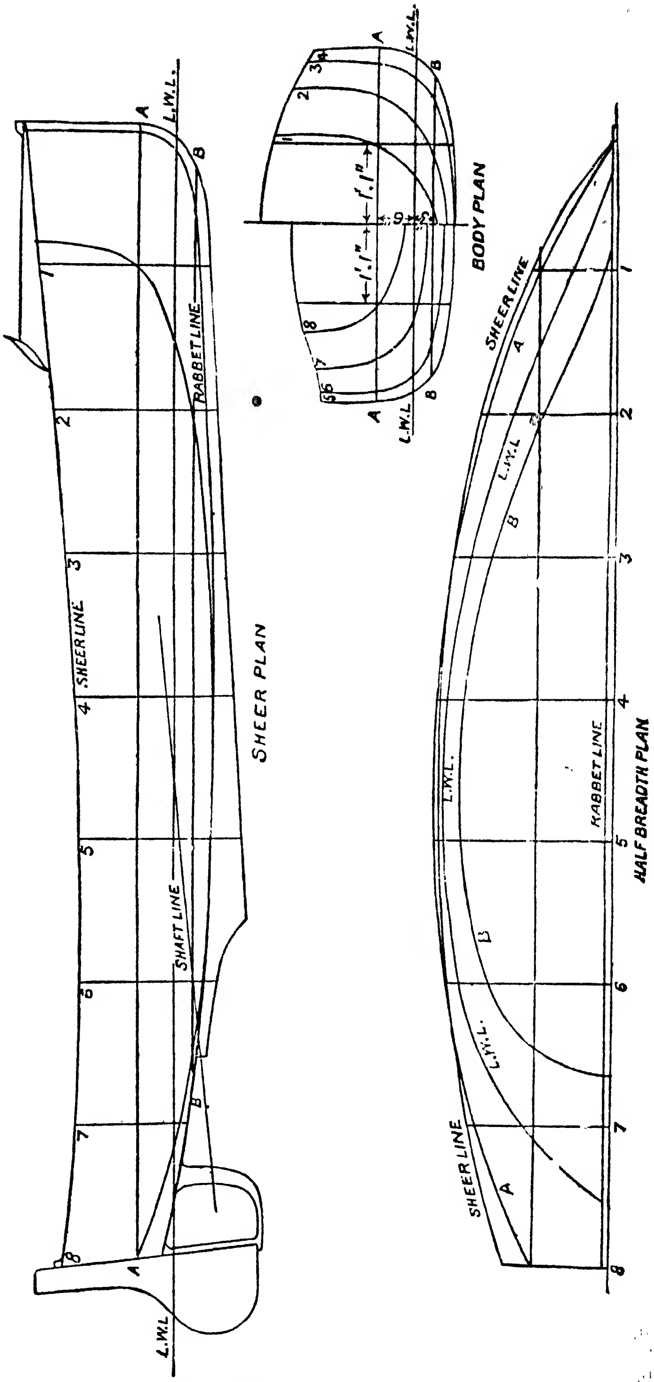


Fig. 1.—Example of lines of a boat.

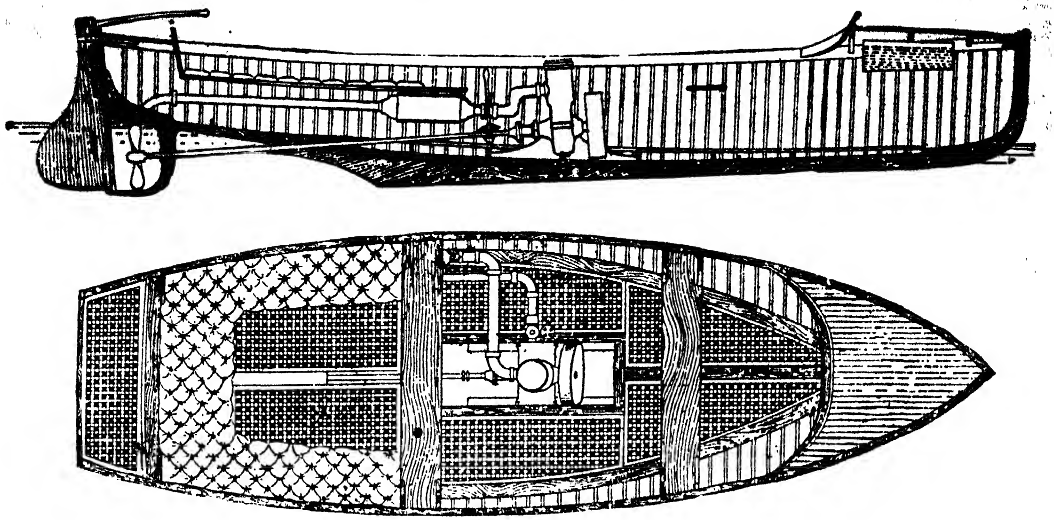


Fig. 2.

scale or full-size drawing of such parts unless the builder is quite clear as to the exact nature of the work required.

Building a 16ft. Boat.

The design of the 16ft. motor boat which we give here is an easy one to build from, as there is no hollow in the after part of the garboards, consequently the greatest trouble of the builder is avoided. The boat may be built either clench or carvel, but, as clench building is entirely a matter of rule of thumb and manual dexterity in the shaping of the planks by eye and experience, it cannot possibly be taught, but is only to be acquired after years of experience. Therefore, we will assume the boat to be carvel-built of ⅝in. planking (finished thickness). In general particulars the specification will follow the lines set out in a previous page as regards materials used, etc.

Laying Off and Making Moulds.

If possible, the whole design of the boat should be laid off full size on the floor or other convenient surface of sufficient size, but, where there is no suitable floor or space, the sections alone may be laid off on a large board or sheet of paper.

The most suitable type of boat to take for this explanatory article is naturally a simple one, not only because less labour and a smaller weight of material are involved, but because the planks and timbers are much easier to handle than would be the case in a larger craft. We therefore take a 16ft. dinghy, as shown in the accompanying designs (Figs. 1 and 2). Such a boat would be quite suitable for a yacht's dinghy, or for a knockabout boat.

In laying off from the small scale design, the floor, board, or paper must first be marked off with the various water-lines, etc., as shown in the design, and the utmost accuracy must be employed to ensure that this basis of the work is correct. Taking the body plan (or sections) first, a vertical centre line should be drawn down the middle of the space on which the work is to be done; then, at right angles to this, draw the load water-line (L.W.L.) in such a position that there will be ample room for the whole of the sections on the space available. The rest of the water-lines should now be placed in their proper places, the greatest care being taken that they are correctly spaced apart, and are perfectly parallel to the L.W.L. and are square to the centre line. The buttock lines, or vertical longitudinal sections parallel to the centre line, must now be put in as vertical lines on each side of the centre line, care being taken that they are exactly parallel to it, the proper distance apart being observed. Having all the working lines laid out, and carefully checked to avoid any possibility of error, we are now ready to lay off the sections. Starting with No. 1 from the stem, take the height of the sheer line off the sheer plan (or profile drawing), and set it up from the L.W.L.; then from the body plan (checking its accuracy by the half-breadth plan) take the half-breadth on deck at this section; where these two measurements intersect is the highest point in the section to be laid off. Next set off from the centre line, on the L.W.L., and all the other water-lines, the half-breadths as shown on the body and half-breadth plans, bearing in mind the fact that, where the offsets (or distances from the centre line) in the body plan and half-breadth plan do not agree exactly owing to errors in the drawing, that measurement is most likely to be correct which is taken at the greatest angle to the section. That is to say, if the water-lines in the body plan cut the section at a very small angle, the point of inter-

section is much more indefinite than it would be where the angle is greater. Consequently in such cases it is safer to trust to the offset on the water-line in the half-breadth plan than that on the buttock line in the body plan which cuts the section at such a fine angle as to make the point of intersection indefinite. The rule that must be observed throughout the laying off is, always place more value on measurements taken from the intersection of lines as nearly at right angles as possible than on lines crossing at a small angle. It may be said that, if the drawing be properly made, there should be no differences in the offsets of any given section, whether they are taken from the half-breadth, body, or sheer plans. Theoretically, this is obviously correct, but in practice not one drawing in a hundred, or, we might say, not one in a thousand, coincides exactly in every point, as it is practically impossible to avoid some slight errors when working to such a small scale, and, even if the error be only the thickness of a line in the design, it may mean an eighth of an inch or more when laid off full size.

The Use of the Batten.

All the offsets in each section must be laid off in the manner just described, and a flexible batten bent round so as to nearly touch each intersection spot, as marked on the water-lines and buttocks. It can either be held in position with weights or with fine wire nails, while a line is drawn round it passing as nearly as possible through all the spots. When fixing the batten, great care must be taken that it bends in a perfectly fair curve throughout; if it will not do this without missing some of the spots, the offset should be checked over again to find out the error, and if no mistake be found in the measurements, the batten should be worked so as to go just inside one spot and outside the next until there is obtained a fair curve which will approximately pass through all the spots. It must be distinctly understood that all the curves, whether of sections, water-lines, or buttocks, must be perfectly fair and true throughout, and if a bad error appears to occur between the offset and the fair curve of the section, it is almost certain to be in the measurement of the offset from the design.

The Stem Curve.

Having laid off all the sections and the transom in accordance with the foregoing instructions, the curve of the stem should be laid off in a similar manner and moulds made to the shape of the stem and each section. These moulds should be made of any common wood of about ¾in. in thickness. The mould must not be the full size of the section, as there is the thickness of the planking to be taken off, the design being usually made to the outside of the plank; the thickness of the planking must therefore be marked off at about every six inches or so all round each section, and another line drawn inside and parallel to the curve of each section.

Marking Off the Moulds.

The simplest and most convenient method of marking off the moulds, in accordance with the laying off, is to lay a lot of tacks on the full-size drawing with their heads about two inches apart exactly on the line of the inside of the planking. Then place the piece of wood from which the mould is to be cut over the line of tacks, and give it a few blows with a hammer to drive the edges of the tack-heads into the wood; on turning it over a line of dents will be found coinciding with the curve of the section on the body plan, and the mould can be cut to this line, planing the edge carefully till it exactly fits the drawing. The best plan is to make the moulds in two pieces, each of which is a duplicate of the other, forming the two sides of the complete mould. These half-moulds are firmly braced together with cross-ledges at the L.W.L. and at the level of the sheer line, care being taken to keep these cross-ledges exactly square with the vertical centre line, which, with the sheer line and L.W.L., must be accurately and plainly marked on both moulds and cross-ledges. Each mould should also be plainly numbered.

Preparing the Floor.

As soon as the moulds are completed, the floor should be prepared for setting up the frame by drawing a central straight line extending for about a foot beyond the length of the boat at each end. In the case of the 16ft. motor dinghy, the centre line should therefore be about 18ft. in length. Along this line the positions of the various sections must be marked off, starting from the fore side of the stem, and marking off the sections every two feet, as that is the distance they are spaced apart. At each of these points a line must be drawn across the centre line, for rather more than the half-breadth of the boat at that section, on each side of the centre line, and accurately squared, so that it is at right angles to it. It is as well to mark off the half-breadths on either side of the centre on these section lines and run a batten round the spots to see that they are fair and correct before erecting the moulds.

Setting Up the Moulds.

The 'midship mould should be set up first, and as most of these small boats are nowadays built bottom up, the mould should be fixed that way with the upper part (the bottom of the boat) about three feet from the floor, which will be about the most convenient height to work at.

In setting up the moulds, a central strut is first erected on the floor, with one edge exactly on the centre line, and one side on the cross line of the section on the floor. In the case of a boarded floor, this strut is fastened down by means of a stout chock or cleat nailed to the floor and to the upright strut, holding the latter firmly in place (in case the floor is only earth, then these struts are driven in as stakes, the centre line being represented by a tightly-

stretched string). The two sides of the mould have each a similar post or strut attaching them to the floor. Before fixing the mould to these struts, the central one must be carefully plumbed upright both fore and aft and athwartships; the mould is then nailed to it with a single nail near the top of the strut, and, when the mould has been properly levelled along the straight edge of the sheer bottom, it can be securely fixed to the central and both the side posts. Fore and aft diagonal stays must be fixed from the floor to the centre post to keep it and the mould upright. The rest of the moulds must be erected and fixed in place in a similar manner, every care being taken to ensure accuracy in spacing, squaring, and plumbing each one as it is set up.

Regarding the spacing of the moulds, which, although some ¾in. in thickness, are shown as a line on the drawings; it is usual to fix the 'midship mould and all those forward of it with their *fore edges* on the section line, whilst those moulds abaft the centre have their *after edges* on the section line. This necessitates the 'midship mould and the one next abaft it being closer together by the thickness of the mould than any of the others; but the object of this alteration in the spacing, from the fore side to the after side of the mould, is to allow for the angle which the side of the boat makes with the mould, and which otherwise would have to be bevelled all round to enable the planking to touch both edges, whereas now only the fore edge of the forward moulds and the after edge of the after moulds touch the side of the boat.

Keel, Stem and Transom.

While the moulds were being set up, the keel and stem should have been got ready, cut to shape, scarphed and bolted together with a brush of thick paint in the joint. The transom should be fitted to the keel, and secured to it by means of the stern knee. Care must be taken that the stem and transom, when attached to the keel, are square with one another, and not, as we remember in the case of our own first attempt, one with a list to starboard and the other over to port.

The keel, stem and transom should all have the centre line clearly marked on both sides, and the positions of each section squared across the keel on top and bottom. The widths of the keel at each section must be measured off and marked on their corresponding moulds, which should have a piece cut out to exactly fit the section of the keel at that point. The keel may now be fitted over the moulds and fixed in place after the rabbet has been cut, the stem and transom being well secured to the floor and roof, their centre lines being first carefully plumbed upright. It is usual to cut the rabbet in the keel and stem as soon as they are scarphed and bolted together, but the final fitting of the rabbet should be left until the whole frame is in place, when it can be faired up with battens over the moulds.

Checking.

As soon as the moulds, keel, stem, and transom are all in place, all the moulds must be most carefully checked over, and all measurements verified to ensure accuracy. They should then be secured to each other and to the stem and transom by fore and aft braces from the outer ends of the cross battens at the sheer line on each mould, and the distance from the centre line of the after side of the stem to the outside of the first mould at the sheer line should be carefully checked on both sides, to see if it is square with the centre line, the same thing being done at each of the others. A pair of stout battens about 1in. by ¾in., tapered to 1in. by ⅝in. in the last two feet of the fore ends, should be bent round all the moulds at the sheer line, and well fastened with 1½in. wire nails to each mould, the transom and the stem, the fore ends of the battens being let into the rabbet of the stem, as if they were part of the planking.

In addition to these sheer battens about four other lighter battens of, say, ¾in. by ⅝in., should be bent round over the moulds from end to end of the boat, to show any unfairness in the moulds. If these battens touch some of the moulds and miss others, it is probable that some of them are not quite in their proper places, or are incorrect, consequently all the measurements must be gone over to find any error, and, if none can be found, the mistake must be in the moulds themselves, and they must be altered until all the battens lie quite fairly on the moulds, touching every one.

A Caution.

We would here warn the builder against cutting away anything from the outside of the moulds until there can be no possible doubt that it is the mould and not the setting up that is wrong, as such alteration of a mould cannot afterwards be rectified. An apparent unfairness of the battens is also due sometimes to some of the battens themselves being unfair, or through the ends being "pinned," while the centre is too slack, thus causing it to buckle unfairly. All battens should be laid over the moulds, the middle being fastened first, and so on to each end.

Marking Off the Keel.

Supposing the moulds to be all faired up and the rabbet in stem and keel to be cut out tolerably near the correct depth and angle, the keel should now be marked off for the heels of the timbers at their specified spacing, care being taken to avoid the moulds when spacing out their places. As the length of the gunwales must always be greater than that of the keel, it follows that at the bluff of the bow on the gunwale the timbers must be spaced further apart than at the keel.

A wedge-shaped notch must be cut out of the back rabbet at each timber station exactly corresponding with the width and depth of the

timber on the outer edge of the keel or stem, but tapered off to nothing in depth at the inner edge of the rabbet.

Timbering.

All is now ready for timbering, and the American elm timbers having been planed up to the correct width and depth must be steamed until they are quite pliable. They are then taken out of the steam kiln, the end cut to fit the tapered notch in the keel, into which it is driven, and lightly tacked if required, being afterwards bent up till it fits tightly, but fairly, under the battens or ribbands on the moulds; this is continued until the whole of the timbers are in place, tacking each one to the sheer batten and any intermediate battens as may be requisite. As the timbers soon get cold and lose their pliability, there must be no loss of time in conveying them from the kiln to the boat and fitting them.

Planking.

As soon as all the timbers have got cold, and set in their places, the first plank may be fitted, and, as this fitting is the greatest difficulty to be overcome in building a boat, it may not be out of place to describe it for the benefit of those who have never built a boat before. The first thing to do is to divide the edge of the 'midship mould in accordance with the number of planks aside (in the present case nine).. The width of these planks should be greatest next the keel, gradually decreasing towards the turn of the bilge, where they should be narrowest, again widening slightly towards the top strake. Always keep the planks narrow where the curve of the mould is sharpest, otherwise great difficulty will be experienced in maintaining fair sectional curves.

The stem rabbet and transom must next be divided into the same number of parts as the 'midship section, so that all the planks will finish at the stem of the same width.

This is most important, as nothing looks so bad as a lot of unevenly-spaced planks up the stem rabbet. On the transom, especially below the turn of the bilge, this is hardly so important, as the curve of the moulds must be considered, and the width of the planks varied accordingly, keeping those above the bilge as even in width as possible.

The Garboard Strake.

The method of fitting the garboard strake, or plank next the keel, is as follows:—A thin flat batten about three or four inches in width and 9 or 10ft. in length is roughly cut to fit the rabbet, when it is bent into place over the moulds. It is next fixed to the moulds by means of three or four tacks, and the edge next the rabbet is then marked to correspond with the exact curve to which it is to be fitted. This is done by drawing a number of parallel pencil lines across the keel and batten at right angles to the centre line of the boat. These lines are *not* at right angles to the rabbet at the curve of the stem, but remain parallel to the line of the moulds. The reason of this is that, on these lines, the distance from the edge of the batten to the back of the rabbet is set out with a pair of compasses or dividers, set to the greatest distance between batten and rabbet, and pricked off on each of the cross-lines, the other leg of the compasses being placed on the edge of the rabbet where the line crosses it. By this means the distance is marked off at each cross-line, and when the batten is cut to these spots it should fit the rabbet fairly well and only need a little planing to make a good joint, the batten being removed from the moulds to be fitted and refastened in place when finished. As soon as the first part is ready, another similar batten must be fitted to the other end of the rabbet, so that the two battens overlap each other about 2ft. amidships, and when both parts are correct they are nailed together where they cross, so that when removed they form one complete mould of the garboard strake.

This mould or batten is laid on a piece of the wood prepared for planking the boat, and a pencil-line drawn round the fitted edge, which may then be cut to shape. The width of this plank is determined by the widths set off on the centre mould, stem, and transom, which are marked off on the plank at their respective points; a stiff square-sectioned batten is then bent through these marks, and another line drawn to mark the outer edge of the plank away from the rabbet. The plank is next sawn out to the pencil-lines, leaving 1-16th in. of wood outside the lines for fitting; it is then offered up in its place and held with cramps while fresh "spilings," or compass distances from rabbet to the edge, are set off as before, unless it be already a fairly good fit. As soon as this is the case, the whole of the rabbet must be chalked and the plank again offered up and driven into place. The plank is then removed and the chalk-marks planed off with a fine plane, and the process repeated until the plank fits perfectly throughout its length. It is a tedious job, but one that must on no account be hurriedly done.

Other Planks.

With the rest of the planks a somewhat similar process is gone through, except that a single long batten is used, and the distances between it and the edge of the last plank marked on it at each cross-line. In bending these "spiling" battens over the moulds care must be taken that they lie flat and fair on the moulds throughout their length, as any forcing or buckling of the batten will only end in distorting the shape of the plank to be cut.

The garboard strakes are the most difficult planks to fit in the whole boat, and if they be a good job, there should be little difficulty in the rest of the planking, anyone having sufficient skill to successfully tackle the first would certainly be able to manage the remainder.

The Long "Spiling" Batten.

On this long batten the distances between it and the edge of the plank just fixed are written down at short intervals, not pricked off with compasses as at first, and afterwards being set off on the wood for the plank. In bending a 'spiling' batten over the moulds, great care must be taken to ensure its lying flat and fair over them throughout its whole length, as any buckling or twisting caused through forcing it sideways or endways will only end in distorting the shape of the plank to be cut.

When using this batten, it should be laid on the wood to be cut and lightly tacked down as before, but as the distances from its edge to that of the fixed plank were written on it instead of being pricked off with compasses, they must now be set off from the edge with a rule, forming a series of spots through which the line is to be drawn to mark the edge of the new plank. The width of the plank at each end and amidships is set off as before, and a batten bent through the spots to give the curve of the outer edge. The plank being cut out and planed up to the lines, it must be tried up in place and roughly trimmed, with a final fitting afterwards, using chalk on the edge of the fixed plank. Any full places on the edge of the new one will thus be marked until it fits throughout its length, and consequently shows the chalk from end to end. From each plank, as it is fitted, a duplicate should be marked off for the other side.

We have, perhaps, gone to an apparently unnecessary length of detail in describing the best method of fitting the planks, but the fact is, so many boats are spoilt for want of proper knowledge and care in fitting the seams, even when built by firms who claim to be good builders, that we feel the necessity for due care in these details cannot be too much emphasised.

Careless Methods.

As an instance of this, we were shown a launch the other day which had been built by a much-advertised firm for shipment abroad. She was carvel-built of teak, and was brightly varnished; a lot of the usual stock pattern brass fittings were stuck about all over her, presumably to take the eye and prevent one from noticing the fitting, or absence of fitting, in the seams, and especially in the plank ends at the stem. Here, instead of the end of each plank fitting close to the edge of the rabbet and forming a narrow fair line of even width all up the stem, the top of one plank would be touching the rabbet, while the bottom, two inches lower down, was nearly 3-16th in. away, the gap being filled up with brown putty. The seams were nearly as bad, and in many places one edge was standing out beyond the edge of the adjoining plank, the inequality in the surface being smoothed over with a charitable cloak of putty.

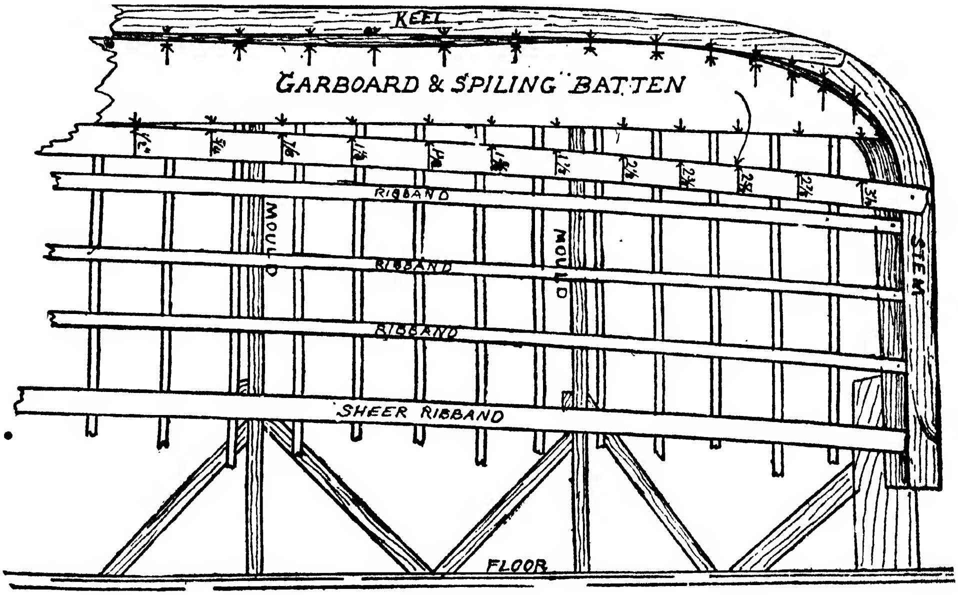


Fig. 3.

A Contrast.

As a contrast to this, we saw elsewhere another launch of about the same size and thickness of planking, but instead of a stem rabbet like an old saw, every plank was an exact fit wood to wood, and the rabbet would hardly have been perceptible if it had not been for the difference in colour of the stem and planking. In this case the boat was just laid up after her second

season of hard use, and yet it was almost impossible to get the point of a knife into a seam anywhere. Such work is a credit to the builder, and in the long run an economy to the owner, as, though he pays a bit more in the first instance, he has no repair bill, and if he keep his boat up properly he can sell her at the end of a couple of years for a much higher price in proportion to that which could be obtained for the so-called "cheap" rubbish, which can only be compared with some of the American-built motor boats with which the British market was inundated a few years ago.

From the foregoing contrast of two different classes of building we think it must be obvious that if we are to keep up this country's reputation of having the finest boat builders in the world, we must not encourage the cheap and nasty class of bad work and poor material which only finds a market owing to the fact that many motor-boat owners know nothing of boats or boat building. Among yachtsmen there is not the same danger of being imposed upon, as they are usually men of considerable experience, who insist on good work, and are willing to pay a fair price for it.

Finishing the Planking.

To return to our planking, we will take it for granted that the work is to be high-class and that no trouble is to be spared to make every seam a perfect wood-to-wood fit. For this kind of seam no caulking is required if the timbers be spaced closely together, and all that is requisite is a brush full of thick varnish along the edges of the two planks as each one is finally fixed in place.

Turning over and Preparing Gunwales.

When the planking is completed the boat must be turned over with the moulds still in her, and set up on stocks to finish off, where she must be securely fixed with struts from the roof to both stem and stern. Before removing the moulds the gunwales should be planed up, steamed, and bent round the boat *outside* the planking and held in place while setting with a few cramps. Light battens, known as cross spauls, must be fixed across the top of the boat with cleats nailed to the ends to grip the outside of the top strake between each mould, so as to prevent the boat spreading or going out of shape in any way when the moulds are removed.

Fastenings.

The moulds may now be taken away and the fastenings through planking and timbers clenched off, either on roves or else by cutting the nail-ends to within an eighth of an inch of the wood and turning them over flush into the face of the timbers. Clenching on roves is the best job for heavy work, but experiments have proved that a nail properly turned on the timber will pull its head through the plank before the clench will draw. This is an item on which a small saving in labour can be made without any detriment to the boat if she be for river or light sea use, but clenching on roves is the best method if the boat is to be beached or likely to undergo a lot of knocking about.

The fastenings being completed, the gunwales should be put in and through fastened at about every other timber. A substantial breast-hook and a pair of quarter knees must be fitted to tie the ends of the boat, and these must be well fastened with at least three through fastenings along each arm, clenched on roves. As the gunwales are placed inside the timber heads a space will be left between them and the planking between the timbers, and as this would look unsightly if left exposed, it is covered with an American elm capping or rail which extends just beyond the gunwale on the inside and projects nearly its own thickness beyond the planking on the outside of the boat, forming a half round nosing or rubbing piece. This is not fitted till the boat is nearly finished, but we mention it now as we are on the subject of fitting the gunwales.

Floor Frames.

The floor frames should be next got out, light templates or patterns being first cut out of thin wood and fitted at each floor station, the floors themselves being cut out by these patterns, not forgetting to cut a water course or limber hole on each side next the keel. They are afterwards fitted down into place with chalk in the same way as the planking, and through fastened in the centre with stout copper nails right through the keel, lighter through fastenings being used at each plank, all clenched on roves. The greatest sectional area in the floors will be where they are joggled over the keel, from which they should taper off to little more than the size of the bent timbers at the ends. The latter should extend well up to the turn of the bilge, and the bilge stringer should be worked over them, being fastened through the end of each floor and also through every alternate timber; the stringers, like the floors, should taper at the ends. When the floors and stringers are fitted and fastened the engine bearers should be got out to a template in a similar manner to the floors and joggled down over the floors and timbers on to the skin of the boat. They must not be forced in any way or they will probably pull the boat out of shape; limber holes must be cut in the underside of each bearer before it is fixed in the boat. A coat of varnish should be put on the under-sides of the bearers, floors, and stringers, and on the planking where they touch it, before they are finally fastened; in fact all joints should be painted whenever they are fitted and ready to be fastened.

Engine Bearers.

Great care must be taken in fixing the engine bearers to ensure their being exactly parallel to and equidistant from the centre of the keel, also to see that they are vertical and not leaning to either side or wider apart at the top than at the bottom. They should be through fas

tened at the ends and over as much of their length as the depth will permit; for the rest of their length they must be closely screwed from the outside of the planking. One or two pairs of light knees of wood or metal may be fitted alongside them on the floor frames just abreast of the motor, unless they have diagonal struts from the top of each bearer to the stringer as shown in the construction drawing of the racing launch on page 26.

The false keel, if not already in place, must now be fitted and well bolted to the main keel every 10 or 12 inches, the joint between it and the under-side of the keel being well varnished as just described.

Stern Tube Chock.

The tapered chock for the stern tube should go in next, and must be most carefully fitted and bedded down on the keel in a thick coat of red and white lead. It must be well bolted through the keel every five inches on each side, leaving sufficient space for the stern tube between the fastenings. It will be noticed that the complete construction drawing of this boat (Fig. 2) shows the stern tube chock in one piece with

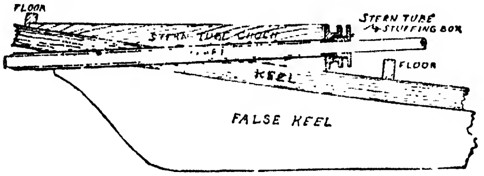


Fig. 4.

the after-part of the keel, which is scarphed to the main piece just underneath the stern tube, the main keel and the part corresponding to the false keel being in one piece.

This is not such a simple method as that previously described and illustrated in the detail sketch of the stern tube (Fig. 4).

The stern tube in this boat runs right through from the stuffing box inside the boat to the skeg in one piece, and is attached to the latter either by screwing it into the skeg direct or else by means of back nuts on the tube on each side of it. The latter method is the simplest, and the one usually adopted.

Thwarts and Seats.

A light flat ribband or rising must be bent round and fastened on the face of the timbers at a suitable height, to carry the ends of the thwarts and the side benches, which may now be put in and secured with the usual knees at each side.

The Deck.

The boat is now nearly completed, so far as the boat-builder's work is concerned, all that remains to be done before she is ready for the installation of the motor being the deck, flooring, and a light bulkhead at the after-end of the deck.

Of these, the deck should be taken next, and the deck beams must be cut out of oak or other suitable wood to the correct sweep, the after, or main, beam being of stouter scantling than the others.

The ends of all the beams should be dovetailed into the gunwales, otherwise they are not tying the two sides of the boat together. If the deck area be large in proportion to the boat, the beams should not only be dovetailed, but all main beams, such as those at bulkheads or at the ends of hatchways and other openings, should have horizontal and vertical knees ("lodging" and "hanging" knees) fitted at each end. Such knees greatly increase the strength of the hull to resist twisting and crushing strains. The upper surfaces of the deck beams and the gunwales must be thoroughly faired up by means of a batten laid over them in every direction, all lumps being planed as they are found, until the batten lies flat, touching every beam, etc.

The deck should be laid in narrow planks

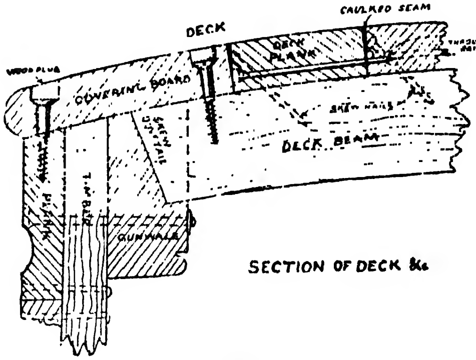


Fig. 5.

tapering towards the stem. The centre, or "king," plank is laid first in the present instance, and is wider than the other planks; it may be of mahogany to form a contrast to the rest of the deck planks, which should be of yellow pine or Kauri pine, carefully picked and free from any sort of mark or discoloration.

All decks should be secret nailed, and the method of doing this is clearly shown in Fig. 5. The king plank is first skew-nailed to the beams on both edges, the nails being punched well inside the edge of the plank, then a plank is laid alongside it and nailed horizontally right through its width into the edge of the king plank, the nails being kept just below the centre of the plank to allow room for the caulking. The outer edge of the second plank is now skew-nailed to the beams, and the process repeated until all the planks are fastened in place.

On reference to the construction drawing (Fig. 2), it will be seen that the deck planks do not run right out to the side of the boat, but are surrounded by the capping or covering board which runs right round the sides of the boat

over the planking and gunwale. The outside of the deck planking must be trimmed fair to the line of the inner edge of the capping, the forward portions of which should not be fixed until after the deck is laid. With a yellow pine deck and mahogany king plank, mahogany capping and coamings look best. At the stern, a similar short deck may be fitted between the transom and the backboard, or alternatively a grating, as shown in the present boat.

Flooring.

The flooring is such a simple piece of carpentering that it needs no further description. It is laid on pine cross-bearers spaced about 12 to 18in. apart, and the only operation that requires any skill is the levelling of the top surfaces of these bearers. A grating floor at most always looks better than anything else, especially for yachts' boats, but it is very expensive to make on account of the labour involved; therefore, in most cases, a plain pine floor is fitted and covered with linoleum.

Bulkhead and Accessories.

A light bulkhead of ½ inch cedar should be fitted at the after-end of the fore-deck, with a doorway of sufficient size to allow the petrol tank to pass through it, but, before it is fixed, the bearers for the tank should be fitted and secured in their places, as it is often difficult to do this satisfactorily after the bulkhead is in. The keel and stem bands and the usual accessories and deck fittings such as fair leads, mooring bollards, flagstaff sockets, rowlocks, etc., etc., should be fitted before the motor is installed, but the rudder and steering gear, such as the wheel, with its wires and leads, may be left until the motor is in place. If intended for use as a yacht's boat, a wheel need not be fitted, as a tiller is all that is required; but, in addition to the fittings just enumerated, a pair of sling bolts must be supplied to enable her to be lifted on davits.

Shaft Line.

The centre line of the shaft should be prolonged on the drawing, until it touches the back of the stem inside the boat, and outside the boat it must be produced aft to intersect a vertical line dropped from the centre of the top of the transom. We have thus obtained two fixed points in this line on the drawing by which we can easily ascertain the corresponding positions of similar points in the actual shaft line on the boat. Two intermediate points must also be marked on the drawing, one just forward of the stern tube chock inside the boat, and the other about a foot aft of where the centre line comes outside the keel, as shown in Fig. 6.

These points will be marked on short vertical pieces of wood nailed alongside the centre line on the keel, so that a line stretched from the point marked on the inside of the stem and passing through the point on the piece of wood fixed to the keel will indicate the exact centre of the shaft line on the fore-end of the stern tube chock, and a similar line outside, taken from the point marked on a vertical batten at the centre of the after-side of the transom through the point on the other piece of wood on the keel, will give us the place where the centre of the shaft line cuts the outside of the keel.

Boring the Hole.

In the present case, the hole may be commenced either from the inside or outside of the boat, and it should be bored first with an auger several sizes smaller than the external diameter of the stern tube, taking every care to keep the auger exactly in the line required, and, if necessary, working from both outside and inside till the two holes meet in the centre. When the auger hole is bored, a line must be tightly stretched from the centre mark on the stem, through the hole, to the mark on the vertical batten at the stern, to which it should be made fast. This line should be exactly in the centre of the two ends of the auger hole in the stern tube chock, if the foregoing instructions have been carefully carried out; and by looking along the line through the hole it will be at once apparent if the latter be true or not.

A boring bar with a cutter set to the exact diameter of the stern tube must be used to finish the hole and make it perfectly true throughout

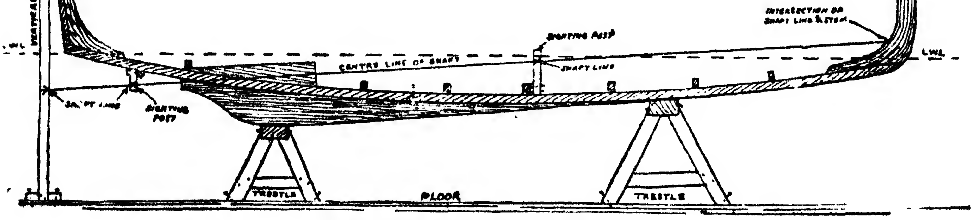


Fig. 6.—Method of setting out shaft line.

its length. This boring bar is usually a piece of rod or tube of slightly less diameter than the preliminary auger hole, and rather more than double the length of the stern tube. It is screwed with a gas thread for about half its length, and at the inner end of the thread a narrow slot is cut through the bar. In this slot a small steel cutter is firmly wedged, and can be adjusted to bore holes of various sizes. Several of these slots are generally cut in the bar, and a cross handle is fixed to the other end of the bar; the screwed end is fitted with a nut in the form of a flat plate which can be screwed on to the forward end of the stern tube chock. The device is shown in Fig. 7. The boring

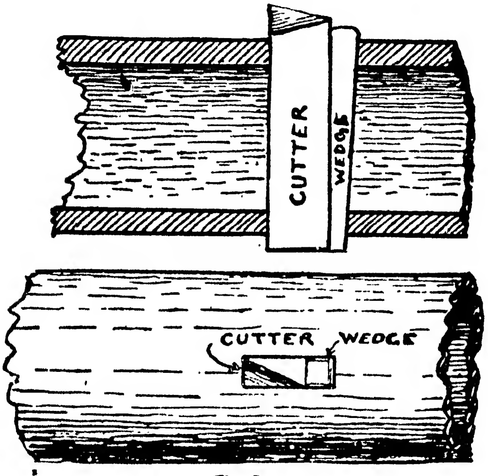


Fig. 7.

bar is now run through the auger hole after removing the line, and the screwed end entered into the plate or nut at the other end of the hole, the cutter remaining outside until a guide block has been fixed to carry the weight of the bar and keep it exactly in line. If the bar be now turned so as to screw it into the nut plate, it is obvious that the cutter will be slowly brought in contact with the end of the hole, and then carried through it, cutting a larger, and perfectly true hole (see Fig. 8) as it is screwed through the plate.

Checking.

As soon as the boring bar has been through the hole, it and the guides should be removed, and the centre line again stretched from the end marks at stem and stern. Should there be any slight discrepancy between this line and the centre of the hole, the line may be moved until it and the centre of the hole correspond, but if, through careless or bad workmanship, the end marks are now much out of the line of the hole, it will be necessary to carefully check all the measurements of propeller and motor to see if there be room to fit the machinery on the new line. If badly out, a new chock must be fitted. The pattern for the propeller bracket, or skeg, and rudder post should now be made, and tried in place to enable the pattern-maker to locate the exact centre of the shaft line on the pattern, by means of the line through the boat, which has been previously described. The pattern can then be completed, and the skeg and rudder post cast in one piece, with a hole in the skeg to take the after-end of the stern tube in the present instance; or, if the stern tube does not project beyond the keel, the hole would then be cast considerably larger than the diameter of the shaft, plugged with lignum vitæ, and bored to the correct size.

Finishing.

The only work now remaining to be done by the builder is the painting and varnishing. A high-class boat should receive at least four to six coats of the best body varnish inside and out. The bottom inside should be coated with three coats of brown oxide paint below the flooring. Outside, if it is not varnished all over, as in the case of most yachts' boats, it should be coated with best white-lead paint, well rubbed down and stopped, and over that a couple of coats of white enamel or Blake's grey racing compound. Another excellent preparation for the bottom of a boat intended to be afloat is copper-bronze powder dusted over varnish which is "tacky," or nearly dry, and to which it will adhere. Two coats of this copper will give an excellent anti-fouling surface.

The remainder of the work of installing the motor is really a fitter's job, and does not come under the head of boat-building; it will not, therefore, be touched upon here.

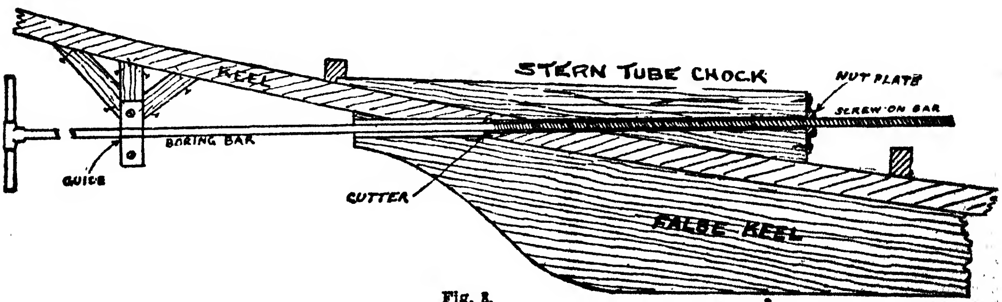


Fig. 8.

THE PRINCIPLES OF DESIGN.

INTRODUCTORY.

Twenty years ago only a few of the builders of small craft had any real knowledge of designing, some of them, especially in the more remote coast ports, being quite unable to understand the meaning of the various lines employed, whilst a larger proportion, even if they understood a drawing, were quite incapable of getting out even the simplest design for themselves.

Nowadays nearly every dinghy builder has some sort of an idea of designing his own boats, or, at any rate, knows enough to lay off a boat full size on the floor from a small scale drawing, and, in many cases, our small boat owners are also clever designers, more especially those who are keen racing men in the small sailing classes

As an instance of the total ignorance of the meaning of the lines on a design, a case may be mentioned which occurred about thirteen years ago. The writer wished to get a rough cruiser built by a coast builder not far from the mouth of the Thames. The man had a good reputation as a builder of fishing boats; in fact, he had won a medal for his boats at one of the exhibitions. When shown the drawing he looked at it for some time, and then, shaking his head, pointed to the buttock lines and said: "No one could ever work a plank round to that shape!" Even when it was explained that a buttock line was only a longitudinal section, he could not be got to see that it was merely a working line in the drawing and not an actual portion of the boat's frame.

Such ignorance as the foregoing is extremely rare at the present day, but there are still a number of builders (and amongst them men who can turn out some really highly-finished craft) who will not attempt to lay off a boat from a drawing, but always require full-size sections and a paper template of the stem, etc.

In spite of the spread of naval architectural knowledge among all but a very small minority, it is, unfortunately, only too common to see small craft of all descriptions with hulls of appalling ugliness, which show only too plainly the want of training and experience on the part of the designer.

Where a builder has been accustomed to build steam launches of one stereotyped form for years, it is no doubt difficult to break away from old habits and adopt the more modern ideas on the subject of the most suitable form for a launch hull, especially as the new designs are usually radically different from the old-established types of river and sea-going launches, the one with her clipper bow and long counter, and the other with a straight keel and sharp rise of floor, all of which are an abomination to modern ideas as being utterly unsuitable for their work.

It is with a view to assisting those builders who wish to go in for designing their boats on modern lines that this article is written; to give a few practical directions as to the simplest way of getting out a motor launch design, and also to try to explain the why and wherefore of the various modifications in type which have proved to be most suitable for each class of work.

It is hardly necessary to go into details as to the proper use of drawing instruments, etc., and in another article on the construction of motor boats the exact meaning of the different parts of a design are fully explained. Therefore, in the present article, it will be supposed that the reader knows how to "read" a design and understand the meaning of all the different sections, water-lines, and other parts of the drawing; also that he has some knowledge of the ordinary drawing instruments and sufficient skill in their use to be able to turn out a decent drawing.

Before proceeding, it is suggested that, in addition to the usual outfit of drawing-board, tee, and set squares, case of instruments, battens, weights and curves, etc., a planimeter and a side rule should also be purchased, as these two instruments will save more labour than can well be imagined by anyone unacquainted with their uses.

The Planimeter.

The planimeter is an instrument by which we can measure the area of any section or other surface, no matter what its shape may be, by simply running the pointer of the planimeter round the outline of the section in the direction of the hands of a watch, the area in square inches being recorded on a revolving drum fitted with a vernier and a supplementary geared disc on which the higher numbers are indicated

To use the planimeter, the needle point under the small weight is stuck into the paper in such a position that the pointer of the instrument may be freely moved over all parts of the body plan or cross-sections of the boat. This pointer is then placed on the point of intersection of the L.W.L. and the centre line on the body plan, and the index or o. on the drum set to zero on the vernier. The pointer is then carefully traversed over the complete outline of the immersed part

of the section to be measured (working always in the same direction as that in which the hands of a watch travel) until the pointer comes to rest once more on its starting place. On looking at the drum of the planimeter we can now read off the area of the section, tens being shown on the disc, units and tenths on the drum opposite zero on the vernier, and hundredths on the vernier itself by noting which mark on the vernier exactly coincides with a mark on the drum. Thus, the accompanying illustration shows a planimeter reading 12.37 square inches, that is to say, 1 on the disc, 2.3 on the drum, and the stroke of 7 on the vernier corresponding with a line on the drum, in this case the line marked 3.

It is usual in an ordinary design to show the transverse sections of the body plan as half sections only, the fore body, or those sections forward of amidships, being to the right of the centre line and the after body to the left. Consequently a planimeter reading of one of these sections as shown on the drawing will only give one half of the actual area of the section, therefore the reading must be doubled, or, what is far better, a second reading may be taken over the same section, thus reducing the liability of error by getting the combined result of two readings and at the same time obtaining the correct area of the section at a glance without any possibility of error due to incorrect multiplication of a reading of half the area. The instructions sent out with the planimeter say that, instead of setting the index to 0. each time before taking the area of a surface, the drum should not be set at all, but the reading should be noted before and after tracing the outline with the pointer and the former subtracted from the latter reading, the result being the area required. This is doubtless the correct method of using the instrument, as it is not only more accurate, but it also prevents the figures on the drum becoming indistinct through constant handling. On the other hand, it entails about three times the work which is required when the index is set each time, and although a small error may occasionally be made in setting the instrument, it is less likely to be serious than the arithmetical errors which may easily occur in hurried working.

By the use of this instrument the displacement of a boat may be calculated in about 20 minutes, whereas, by the old method of a displacement sheet and the measurement of ordinates, it used to take an hour or two and the result was much more liable to error.

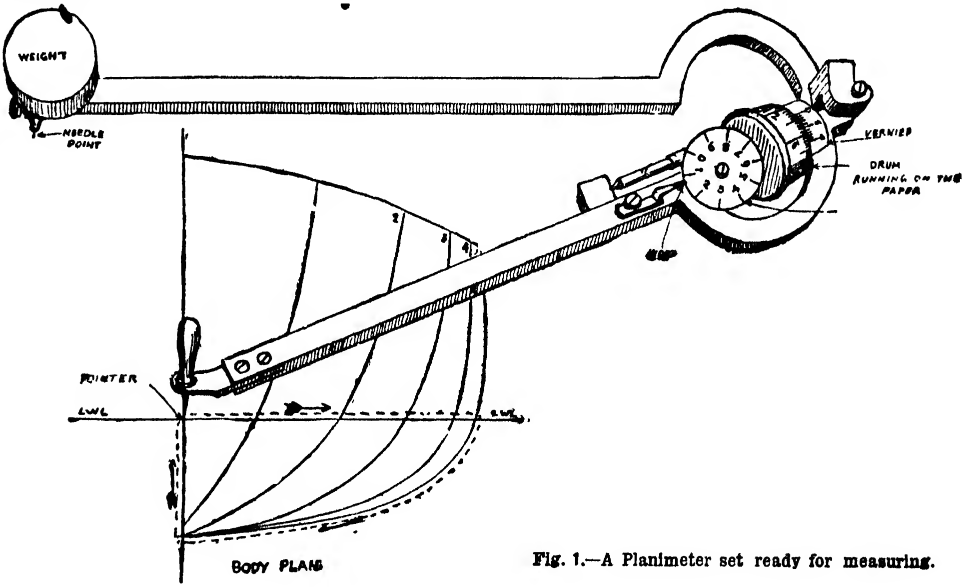


Fig. 1.—A Planimeter set ready for measuring.

Planimeters vary considerably in price and design, but the simplest form, giving a reading in square inches only, is all that is required, as, if the drawing is to any other scale than one inch to the foot, the reading can be reduced or enlarged to suit by means of the accompanying table. (Example :—If the drawing is to a scale of ½in. to the foot, all readings of the planimeter must be multiplied by four, as there are four square half inches in one square inch.)

Scale.	Multiplier.
1" = 1' 0"	0·000
¾" = 1' 0"	1·777
½" = 1' 0"	4·000
¼" = 1' 0"	16·000

It is of course simplest when getting out the displacement from a ½in. scale drawing with an inch scale planimeter to take all readings as if the drawing were to 1in. scale, and then multiply the whole result by four, but always remembering that the interval between the sections

must be taken in accordance with the scale of the drawing and not in accordance with the scale of the planimeter.

The Slide Rule.

This instrument does for ordinary calculations (excepting addition and subtraction) exactly what the planimeter does with regard to the calculation of areas; that is, by means of the slide rule, a close approximation can be obtained at once of the result of multiplying or dividing any given combination of figures. It will also give the squares and cubes with the corresponding roots of any numbers. But its uses are so various that they cannot all be described in detail here. Suffice it to say that its use can be learned by anyone of ordinary intelligence in a day or two by means of Pickworth's excellent handbook on the subject, and, once learned, it is invaluable in all sorts of calculations for every class of work.

Calculations.

When designing any sort of vessel there are a certain number of calculations which must be made if the vessel is to be anything more than a rule-of-thumb job which may or may not float right side up. To make these calculations, a fair knowledge of decimal arithmetic is absolutely necessary, but great mathematical skill is not required. Chief among these calculations is that of the displacement, but before giving the method of ascertaining it we will explain exactly what displacement is.

Displacement.

Dixon Kemp, in his invaluable work on yacht architecture, gave the most lucid description of an experiment which at once explains the whole question. So, with due apologies for borrowing his illustration, it is given here. He takes a small bowl filled exactly to the brim with water so that it cannot hold a drop more, and, standing it in a larger bowl or tray to catch the overflow, he then places a saucer on the water, which immediately overflows until sufficient water has been displaced in the bowl to allow the saucer to float. The amount displaced is therefore exactly equal in bulk to the portion of the floating saucer which is below the water level, and, as may easily be proved by weighing the water which has overflowed against the saucer itself, exactly the same weight as the saucer. Consequently, the displacement of any vessel is exactly equal to the number of cubic feet contained in her under-water body, and the weight of this number of cubic feet of water is equal to her total weight when floating to that given water-line.

From this it will readily be understood that, upon the correct estimate of the weights of the complete boat and crew, the total displacement must be determined, and upon the accuracy of the calculation of the displacement from the drawing depends the whole question of the boat floating to her designed water-line.

Simpson's Rule.

Before attempting to calculate the number of cubic feet in the under-water body of a boat, it is necessary to understand how to find the area of each section in case a planimeter is not available. This is usually accomplished by means of Simpson's rule, by which any area bounded by a curve more or less approaching an ellipse, parabola, or other similar form, can be measured within a reasonable degree of accuracy by means of a series of ordinates which divide the area into an even number of equal parts—say, ten, as shown in the accompanying diagram (Fig. 2), in which the ordinates are numbered from 1 to 11 and are spaced 1ft. apart.

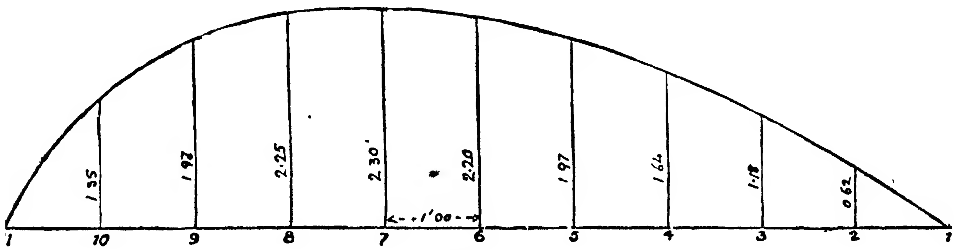


Fig. 2.

It is usual to set down the lengths of the ordinates in columns as follows:—

No. 1	=	0·00	×	1	=	0·00
2	=	0·62	×	4	=	2·48
3	=	1·18	×	2	=	2·36
4	=	1·64	×	4	=	6·56
5	=	1·97	×	2	=	3·94
6	=	2·20	×	4	=	8·80
7	=	2·30	×	2	=	4·60
8	=	2·25	×	4	=	9·00
9	=	1·97	×	2	=	3·94
10	=	1·35	×	4	=	5·40
11	=	0·00	×	1	=	0·00
						3)47·08
						15·69

From this table it will be seen that the two end ordinates are multiplied by 1, and all the even numbers by 4, while the odd numbers from 3 to 9 are multiplied by 2. The results are then added, giving in this case a total of 47.08, which must be multiplied by one-third the distance which the ordinates are spaced apart. In this

instance the spacing is 1ft., so we have to multiply by one-third of one, or, in other words, divide the sum of 47.08 by 3, the result being the number of square feet in the given figure or area = 15.69.

Now, supposing we have calculated the area of each of the sections on the body plan of our boat by this means, we then have a series of areas of sections, and, by treating these areas as the ordinates in a fresh calculation, we obtain the volume of the whole mass in cubic feet, by multiplying the areas of the various sections by the same rule as before and the result by one-third of the interval between the sections, the whole sum being precisely the same as that used to obtain the area of the sections.

Where a planimeter is used the readings from each section are set down at once as ordinates in the final calculation for the total cubic feet in the vessel; consequently only one calculation is required, instead of at least nine or ten, which would be necessary in the ordinary way.

Having obtained the displacement of the boat in cubic feet, it is usual to reduce it to tons, or, in the case of very small craft, to lbs. The number of cubic feet must therefore be divided by 35 to bring it to tons in sea water, or 36 for fresh water, or else multiplied by 64 to bring it to lbs. for sea water and by 62.4 for fresh water.

Centre of Buoyancy.

Next to the displacement, the fore and aft position of the centre of buoyancy is the most important matter to be determined, as the reader is assumed to have enough knowledge of boats to have made ample allowance for stability in getting out the drawing. To find the distance of the centre of buoyancy aft of the stem we must take the sums of the various sectional areas obtained by Simpson's rule as already described, and, *omitting No. 1*, multiply No. 2 by one, No. 3 by two, No. 4 by three, and so on. These products are then added, divided by the sum of the results of the sectional areas, in this case 47.08, and the total multiplied by the spacing or interval between the sections, the result being the number of feet from the centre of buoyancy to the stem or No. 1.

It may be as well to explain that the centre of buoyancy is the exact centre of the whole immersed mass of the vessel. It will be moved forward or aft as the vessel is depressed in the water at either end, or it will move to either side as the vessel rolls, but, no matter what the shape or position of the vessel may be, the centre of buoyancy is always the centre of the immersed body or of the space which the vessel occupies in the water.

To find the vertical position of this centre relatively to the water level we must take a series of horizontal sections or water-lines parallel to the surface of the water, and, having found their areas, we must multiply them in exactly the same way as we have done the vertical sections and divide by the summed results as before. The water level is taken as No. 1, and the number of these water-lines being odd, the result is then multiplied by the interval, which will give the distance in feet below the water level.

Centre of Gravity.

To determine the position of the common centre of gravity of the boat, motor, propeller, crew, and the various accessories, such as fuel tanks and other fittings, entails a considerable amount of careful calculation, combined with an accurate knowledge of the weights of all the details which go to make up the total weight of the boat when in running order.

The general principle by which the position of the common centre of gravity of the various parts is ascertained is as follows: The centre of gravity and weight of each item is determined separately, and the distance from this point, to a vertical line touching the fore side of the stem, is then set down in a column, the weight being set down in a similar and parallel column, while in each case the distance from the vertical line is multiplied by the weight, and the result set down in a third column. The column of weights and the column of results are each added, and the sum of the results is then divided by the sum of the weights, the quotient being the horizontal distance of the common centre of gravity abaft the fore side of the stem. If we now draw a horizontal line parallel to the water-line just below the bottom of the boat, and then multiply the weight of each item by the distance from its centre of gravity to this line, we obtain a second series of results, which must be treated as before to obtain the vertical distance of the common centre of gravity above the base line. The intersection of the vertical and horizontal measurements determines the exact position of the centre of gravity on the sheer plan, and if the weights are evenly distributed on each side of the centre line of the boat, there will be no need to calculate its transverse position, as it will coincide with the centre line. As regards the fore and aft position of the centre of gravity, it is usual to keep it a trifle forward of the centre of buoyancy as shown when the boat is on her designed load line, because nearly all motor boats have some tendency to raise the bow and sink the stern to some extent when running, and this tendency increases very rapidly as the speed becomes greater, although it is obviated to a considerable extent by flattening out the afterbody and fining the entrance, but this will be explained more fully later on when we deal with the question of the form of the hull; at the moment we need only concern ourselves with this tendency in so far as it affects the fore and aft position of the weights.

In the case of those boats which are not designed for any great speed, the centre of gravity should not be more than one or two per cent. of the length of the boat forward of the centre of buoyancy, and it must be remembered that the weight and position of the crew and passengers constitute most important factors to be taken

into account in making the calculation for the fore and aft position of the centres, although a slight error can be adjusted by altering their position in the boat.

Centre of Gravity in Racing Boats.

In the case of a boat designed for racing purposes it is much more important to adjust the weights accurately, as, if she does not run on an even keel when at her top speed, it is quite clear that she is not on her designed water-line, consequently her under-water body is not in the least like that of her design, and no accurate data can be obtained as to its actual form if she has several feet of her bow out of water when running fast. To counteract this tendency to "get up on her hind legs," the centre of gravity may be placed so far forward of the centre of buoyancy that in the case of a 40ft. boat she is at least a couple of inches down by the head when at rest, but the exact amount of allowance that has to be made can only be determined by experience, as it varies with the design of the boat and also with her speed, so much so that, whilst the bow would continue to rise as the speed increased up to a certain point, after that it would tend to come back nearly to its normal position as actually occurred this year with "Scarlet Runner." For this reason it is always advisable to so arrange the fuel tanks that their positions can be moved fore and aft without much alteration to the rest of the interior arrangements. By this means the position of the centre of gravity can be varied at will

Centre of Gravity of the Hull.

Before leaving this subject it may be as well to indicate the method employed to find the centre of gravity of the hull itself, as this is a much more complicated business than it is in the case of the motor, fuel tank, and the other accessories.

The weights of the keel, gunwales, stringers, etc., are taken separately, and their centres of gravity assumed to be at the mid-overall length of the boat, as they are more or less of one sectional area throughout their length. The engine bearers are also easy to calculate, and their centre of gravity may be ascertained by cutting out a stiff piece of paper to the correct shape and balancing it on the point of a needle, which will indicate the exact position of the centre, provided they are to be of uniform thickness throughout their length; if, however, they vary both in thickness and depth they must be divided into, say, ten equal parts and the correct sectional area ascertained at each section, as in the case of the rest of the hull. To get at the centre of gravity of the planking, timbers, and deck (if the latter be of similar scantling and material to the skin), we must find the perimeter or girth of the hull at each section of the body plan, allowing for any opening in the deck, and treat the number of feet in the girth of each section as an ordinate, to be multiplied in the same way as in the calculation of the areas for the displacement. By this means we get, first, the area of planking and deck in square feet, and, second, by the use of the same rule that we employed to find the centre of buoyancy, we can find the fore and aft position of the centre of gravity.

To find the weight, we have only to ascertain the weight of a square foot of planking and timbers combined, and, taking the deck and deck beams as approximately of the same weight, we multiply the total area of plank and deck by this weight. If absolute accuracy be required, the planking and timbers must be taken separately from the deck, and the centre of gravity of each obtained as before.

To find the vertical position of this centre of the planking, etc., the centre of the girth must be marked on each half-section of the body plan and the vertical distances from these centres to the base line multiplied by the girth in each case as previously described.

Graphic Method of Finding Centre of Gravity.

A simple method of getting a common centre of gravity of two bodies by means of a diagram is as follows: A (Fig. 3) represents the centre of gravity of one body whose weight is, say, 250lb., B is the centre of gravity of another body weighing 140lb. Draw a line (A-B) connecting the two

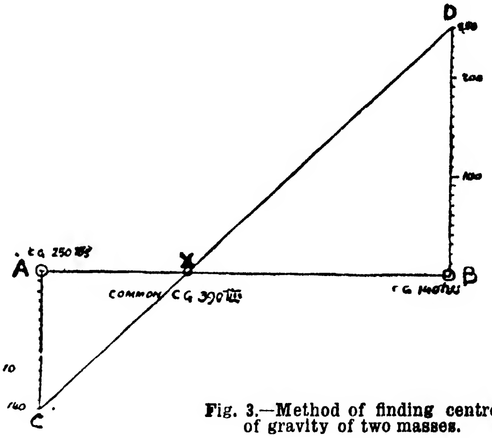


Fig. 3.—Method of finding centre of gravity of two masses.

centres and, at A, erect a perpendicular to the line (A-B) and set off 140 parts of scale on this line at C, next erect a similar perpendicular from B, but on the other side of the line (A-B), and on this line mark off 250 parts to the same scale at D, connect C-D by a line intersecting A-B at X, which is the common centre of gravity of the two bodies. By this method all the various centres may be resolved into one common centre if desired, instead of by calculation, and this is the best way of finding where the centre of any new item must be placed, with regard to that of any other item already in place, to bring the common centre of the two on a fixed point. This is done by drawing a line (A-B) (Fig. 4) from the centre of gravity of the fixed body (A),

through the point (X), which is to be the common centre. A perpendicular (A-C) is then set up at A, corresponding in length to the weight of the new body (D), and a parallel line to A-B is drawn on the other side at a distance propor-

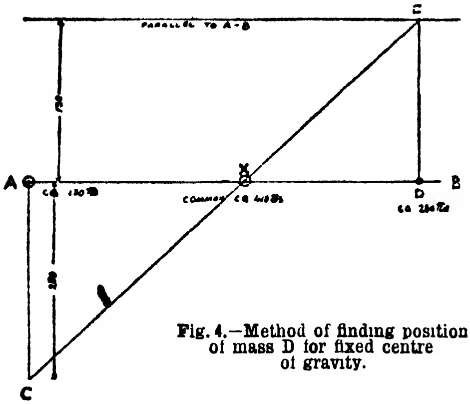


Fig. 4.—Method of finding position of mass D for fixed centre of gravity.

tional to the weight of A. By drawing a line from C through the common centre (X) until it intersects this parallel line, we get a point (E) from which we can draw a perpendicular to A-B, cutting it in the point (D), which is the correct place for the centre of gravity of D if the common centre of A and D is to be at X.

These details are undoubtedly wearisome, but they must be mastered before a racing boat can be attempted, and the more care that is taken in these matters the less chance there is of the failure of the boat from a bad disposition of the weights.

Area of Wetted Surface.

This is a very simple calculation in which the under-water girth of each section is taken, and treated as an ordinate as in the previous calculations for areas, the result being the area of wetted surface of the hull.

Stability.

The necessity for ample stability is so universally appreciated that it is usual when designing a boat to give her more than is really needed for safety, and for cruising purposes any error in this direction is a fault on the right side.

With a racing boat, however, we may get a much smaller margin of safety, and it is therefore necessary to ascertain the exact amount of stability for each boat, especially if the beam be small and the centre of gravity of the motor be high up.

It will usually be sufficient if we have a fair amount of stability left when the boat is inclined to the deck edge, and to ascertain this we must make a diagram showing the 'midship section of the boat inclined to this angle, showing the centre of gravity (which always remains in the same place relatively to the whole body of the boat) and the centre of buoyancy which will be found to have moved out towards the side which is depressed. The exact position of the centre of buoyancy when the boat is heeled can only be determined by a long and complicated calculation, which is unnecessary for all ordinary purposes.

Instead of this calculation, we may assume that the 'midship section in a motor launch of normal type will have nearly the same immersed area when upright as it would have when inclined; therefore, we will take it as being the same in both positions.

To ascertain the centre of buoyancy when the boat is inclined, we must first get the correct inclined water-line on the body plan, and then find the centre of each immersed section, which may be done either by calculation as previously described, or the section may be cut out and balanced on the point of a needle and the common centre of all the sections obtained by calculation as before.

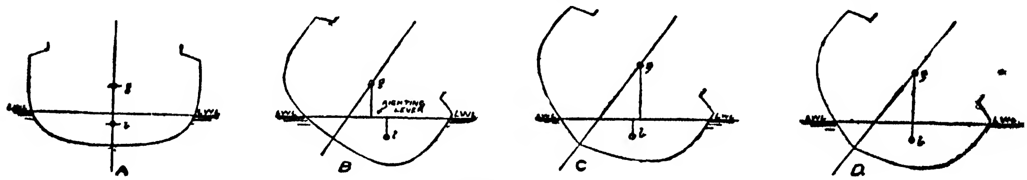


Fig. 5.

Two lines are now drawn, one from the new centre of buoyancy, and one from the centre of gravity, perpendicular to the new water-line; if the two lines coincide, the boat is exactly in equilibrium. If the line representing the downward force of the centre of gravity be outside the upward force of the centre of buoyancy, then the boat will at once capsize; but if, on the other hand, the centre of gravity be inside the centre of buoyancy, the boat has stability, or a tendency to resume an upright position, and the amount of this stability may be found by multiplying the distance between the parallel lines representing the upward and downward forces at the centres of buoyancy and gravity by the total displacement of the boat, the result being the righting moment at that inclination in foot-pounds. In the accompanying diagrams (Fig. 5), A shows the 'midship section of a launch when floating on even keel, *b* being the centre of buoyancy, and *g* the centre of gravity. It will be seen that *g* is considerably above *b*, but when the boat is upright they are both in the same vertical line, and

the boat is in equilibrium. If the boat be inclined as shown in B, then a line drawn from *b*, *perpendicular to the water-line, will pass outside a similar line drawn from g, consequently the* boat at this particular angle has a righting lever equal to the distance between these lines. If, on the other hand, we take another boat (C) with a different section, and with her centre of gravity raised in consequence of higher engine weights, then we find, when she is inclined to the deck edge, that the perpendicular from *g* falls outside *b*, showing that the boat has no stability at that angle. The fourth section (D) shows another boat which is just in equilibrium when inclined to her deck edge; but, of course, we should require a margin of safety and a compromise between D and B is as far as we dare go in this direction, whilst the more stability we can get, by keeping all weights low, the better.

The other calculations, such as those required for ascertaining power or speed, and the dimensions of the propeller, will be dealt with later on.

System in Designing.

It is of the greatest importance that some regular method or system should be employed in getting out a design, and that the old rule-of-thumb practice of making a design by eye without any particular rule as to the disposal of the displacement throughout the length of the vessel should be abandoned in favour of a more precise method.

To this end it will be well to adopt Colin Archer's "wave-form" of body as a basis on which we can construct our design, although the exact "wave-form" of body in accordance with his theory is not necessarily the most suitable for motor launches intended for high speeds.

The "Wave-form" Theory.

The "wave-form" theory is, that a vessel should be so designed that the curve of sectional areas of the fore-body (or that part forward of the greatest transverse section) shall conform more or less closely to a curve of versed-sines, while the curve of areas of the after-body shall be a trochoid.

This theory is based on the assumption that the bow wave created by the passage of the fore-body through the water is a wave of the first order, or a wave of translation, the normal form of which closely approximates to a curve of versed-sines, and that the body of water so displaced closes in at the stern in the form of a replacement wave of the second order, having a more or less trochoidal form.

At low speeds this theory is no doubt correct to a certain extent, but, for our purposes, it serves as a basis on which to construct a curve of sectional areas rather than as a hard-and-fast rule to which all designs should conform. In fact, we should probably never design a boat exactly in accordance with a true "wave-form" of body, as experience teaches us that a considerable percentage may, with advantage, be cut off the extreme ends of the curve, and that this "snubbing" of the curve *may be increased with the proposed speed of the vessel until 10, or even 15, per cent. is re*moved.

Curve of Sectional Areas.

Before proceeding with an actual example, it will be well to clearly explain what is a curve of sectional areas, and it may be described as a graphic method of recording the displacements and sectional areas of a vessel, in such a manner that a curve represents the exact disposition of the vessel's displacement throughout her length. Ordinates to this curve, when spaced similarly to the sections in the vessel, will represent in linear measurement the area of the corresponding section in square measure, one linear foot to scale representing one square foot, and so on.

To make this clear, we will take a typical curve of areas of a motor launch designed for moderate speeds (Fig. 6).

In this case, the base line (AB) is drawn to the same scale as the load water-line of the proposed boat, and is equal to it in length; it is also divided into the same number of equal parts as there are sections in the design, the spacing of the sections being the same as the divisions on AB, viz., 2.30ft.

Having divided the base line to correspond with the L.W.L., we must set off at the mid-section (No. 6) a distance, in feet and decimals of a foot to any convenient scale, equal to the area of the mid-section in square feet, in this case 2.25ft. (C-6). Then, with half this distance as radius (1.125ft.), and the centre of the line (C-6) as centre, describe a circle called the generating circle, which must then have its circumference divided into any convenient number of equal parts, say eight.

Curve of Versed-sines.

The base line (AB) must now have 2½ per cent. of its length added to each end, making a total of 5 per cent., as shown at A^1, B^1. The distances ($A^1 6$ and $B^1 6$) are then divided into four equal parts each, at *e-f-g* and *h-i-j*, and from each of these points a perpendicular is erected. A series of lines parallel to AB is then drawn through the divisions on the circle. These lines will cut the perpendiculars as shown at the points o o, etc., and a curve drawn through these intersections will be a curve of versed-sines, which is correct for the fore-body of the boat, but would be rather too fine for the after-body.

Trochoid Curve.

To obtain a fuller curve we may use a trochoid instead of the curve of versed-sines, or any intermediate curve we may think desirable, such as the one illustrated. The trochoid is obtained in a similar manner to the curve of versed-sines, but instead of drawing the curve through the intersections of the vertical and horizontal lines, as for the versed-sines, we take *the horizontal distance from the centre line* (C6)

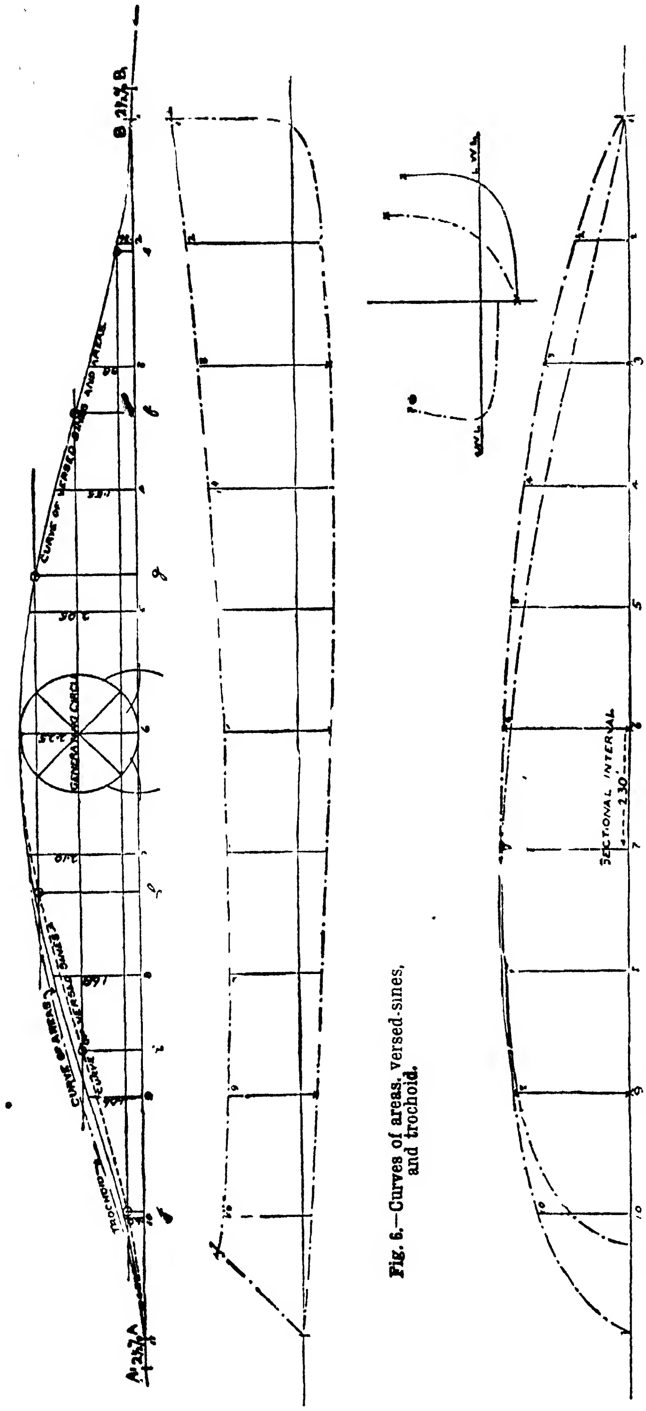


Fig. 6.—Curves of areas, versed-sines, and trochoid.

to the circumference of the circle, and set this amount off on the corresponding horizontal line, from the point of intersection which would be used for the curve of versed-sines. Or any intermediate proportion of this distance may be employed according to one's ideas.

If, when we have completed the curve of areas, we now draw ordinates to the curve at the stations corresponding to the sections 1, 2, 3, 4, etc., we shall obtain a measurement of each ordinate in *linear feet* to scale, which will equal the area of that section in *square feet*, just as the diameter of the generating circle equals the area of the 'midship section. From these areas we can at once calculate the displacement of the vessel before the design is commenced. The only data required are the length on L.W L. and the area of the 'midship section, on which to construct our displacement curve of areas.

Area of 'Midship Section.

The area of the mid-section is easily obtained as follows, when the approximate displacement has been decided on for a given L.W.L. :—

Multiply the displacement in tons by 35—for salt water (or, if it be in lbs., divide by 64), then divide by the length of the L.W.L. and by the prismatic coefficient most suitable for the particular class of vessel contemplated, in this case, say, 0.55. The result is the area of the mid-section in square feet.

Prismatic coefficient.

This prismatic co-efficient is a figure representing the relation which the average of all the sectional areas would bear to the area of the mid-section, and varies from 0.30, in a few very hollow-ended vessels of old-fashioned type, to 0.70 in some modern high-speed vessels of the destroyer type For boats of moderate speeds, with no superfluous deadwood, it will generally range from 0.50 to 0.55.

Order of Procedure.

From the foregoing, it will be seen that on commencing to design a boat, we must first decide on her length and approximate displacement, then from these, being guided by experience in estimating the prismatic co-efficient, we next find the area of the mid-section. Using this as the diameter of our generating circle, we construct a curve of

versed-sines for the displacement of the fore-body, and if the boat is to be fast, a similar curve for the after-body, or any modification between the curve of versed-sines and a trochoid, according to the internal speed and other considerations which experience alone will dictate; these considerations also apply to the percentage to be added to the length of the L.W.L. as a base line for the curve.

Having now obtained the area of the mid-section, and, from the ordinates in the curve of areas, the areas of all the other sections, we can calculate the displacement and the fore and aft position of the centre of buoyancy, and can then proceed with the drawing of the design itself.

Getting Out the Design.

Having decided on the scale to which the design is to be drawn, we must first draw the L.W.L. as a base line upon which to work. At some little distance below it, draw another line, parallel to it, to form the base line for the half-breadth plan, taking care to leave space between the two for the under-water body of the boat below the L.W.L. and the whole of the body plan above the half-breadth plan. Space may be economised if the body plan is placed at one end of the space between the sheer and half-breadth plans.

The length over all and on the L.W.L., together with the extreme beam, must now be decided and set off on the sheer and half-breadth plans, both of which must then be carefully divided to correspond with the stations for the cross sections of the body plan. As we have already seen, it is simplest to divide the L.W.L. into 10 equal parts. Having carefully checked the spacing of these sections, two or three times over, we can now sketch in the L.W.L. and deck plan on the half-breadth plan and the sheer line on the sheer plan.

From them, we can get the approximate half-breadths for the mid-section at the deck and L.W.L., which will enable us to draw the correct mid-section to correspond with the area shown on the curve of displacement (Fig. 2).

This can only be arrived at by trial, as the section has to agree with both the half-breadths and the pre-determined area, and at the same time be of the shape required. It must therefore be drawn as nearly as possible to the correct shape and area by eye and then carefully measured with the planimeter, alterations being made as required until both form and area are correct.

The mid-section will now give us fixed points on the sheer plan for the under-side of the keel and the sheer line, and, on the half breadth plan, it will fix points in the deck line and the L.W.L.

Once the mid-section is correct, we can take an intermediate section about midway between it and the stem on the one hand, and another between it and the stern on the other hand. Each of these sections is found in the same way by making an approximate sketch first and altering it until a correct planimeter reading is obtained.

By means of these three sections, it should now be possible to put in the sheer line and all the profile of the boat on the sheer plan, and finally correct the deck line and L.W.L. on the half-breadth plan.

This will have no doubt proved a tedious bit of work at first, but once it is done the worst of the job is over, as the other sections will be found to fit into their places quite easily, provided the first three are correct and the L.W.L., deck line, and profile are fair.

Fairing Up.

The design is now ready for fairing up; or, in other words, adjusting all errors and inequalities in intersections of the various lines on the sheer, half-breadth, and body plans, until all intersections on the three plans are accurate, and all the lines are perfectly fair and true curves throughout the design. For this purpose a longitudinal vertical section, or buttock line, and in most cases a diagonal as well, must now be put in to check the others.

This fairing is often a work of considerable difficulty if the boat is merely designed by eye, especially if the designer has not had much previous training and experience. With the method here described, however, if the L.W.L., sheer line, and the line of the underside of the keel are all fair to start with and suitable to the 'midship section, there should be no trouble whatever in fairing up the boat; in fact, the curve of areas practically ensures a fair boat.

There is no need to go into all the details of the work of finishing up the design, as that will vary considerably according to the skill and taste of the designer, but there is one important matter to be considered, and that is the position of the propeller and shaft line.

Propeller and Shaft Line.

The question of propeller design is dealt with in another chapter, but at the same time we would strongly advise readers not to attempt to design their own propellers, as this is a subject which is very little understood except by a few men who have made it a life study and have an endless stock of data to work from.

Until the diameter of the propeller is known, the shaft line cannot be put in if the boat is a shallow-bodied modern type of boat similar to the one taken to illustrate these articles, and, unfortunately, no one but the designer of the propeller can say what this diameter should be exactly, owing to the fact that no two propeller designers appear to agree on a standard proportion of diameter.

Roughly speaking, it may be taken as an axiom that for a given hull and power the diameter will increase as the revolutions decrease, and vice versâ; for instance, a 25ft. boat similar to the example just mentioned, when

fitted with a 5b.h.p. motor running at 450 revs., required a three-bladed propeller of 18in. diameter and attained a speed of 8½ miles an hour; while a similar boat fitted with an engine of about the same power, but running at 900 revs., has a propeller of only 14in. diameter.

To give an idea of the difference of opinion among experts on the question of diameter and number of blades, we may mention the case of one boat for which two propellers were ordered from different firms, both being specialists on this work. The boat was a 40ft. racer, fitted with a motor which was stated to be 180b.h.p. For this one designer supplied a two-bladed propeller of 34in. diameter; while the other propeller was only 24in.!—both, however, being somewhat alike in blade area.

When experts disagree to this extent it is obviously hopeless for the ordinary man to say off-hand what diameter is most suitable for given conditions, although a rough guess can usually be made sufficiently close to decide on the clearance required.

A better way, however, is to send the length, displacement, and area of the 'midship section of the boat, together with the power and revolutions of the motor, to the propeller designer you have decided on, and he will tell you the diameter he requires clearance for.

The diameter being obtained, set off a point below the bottom of the boat, as far aft as possible without interfering with the rudder, equal to the half diameter of the propeller, plus at least two inches for clearance. A tracing of the outline of the motor to the same scale as the design must now be made and placed on the design in such a position that the centre of gravity of the motor will come on the spot intended, the lowest point of the motor being an inch clear of the bottom of the boat.

A line drawn from the centre of the propeller to the centre of the after coupling on the motor shafting will then give the shaft line, and a transfer of the tracing of the motor can then be made on the design to correspond with this shaft line.

From this the engine bearers, stern tube, and chock, and the positions of the door frames can be set out and the other details of the construction drawing filled in.

The Effect of Various Forms of Hull.

In what has preceded, we have considered the effect of the distribution of the displacement in the form of a curve of versed-sines for the fore-body and a similar form (or some intermediate curve between it and a trochoid) for the after-body. It must, however, be clearly understood that the curve of areas of sections which represents the distribution of the displacement can be varied to an enormous extent either by moving the generating circle fore and aft, or by snubbing the ends of the curves from the small amount of 5 per cent., as shown in our example, to 10 or 15 per cent. for high-speed boats, as already explained.

In addition to these variations of the general distribution of bulk, the actual form of water-lines, sections, and profile can be varied very considerably on one given curve of areas.

We must now consider the result of the various forms which may be produced from our displacement curve. First, as to the form of the section. Compactness is always of very great importance in the section of a mechanically-propelled vessel, in order to avoid any unnecessary wetted surface, while a fairly flat floor is needed to give stability.

Now, the most compact form of section would be a semi-circle, as may be seen from the following examples (Fig. 7), all of equal area :—

	A. Triangle	B Rectangle.	C. Semi-circle.
Beam ... =	2·00ft.	2·00ft.	2·00ft.
Depth ... =	1·57ft.	0·79ft.	1·00ft.
Perimeter =	4·00ft.	3·58ft.	3·14ft.

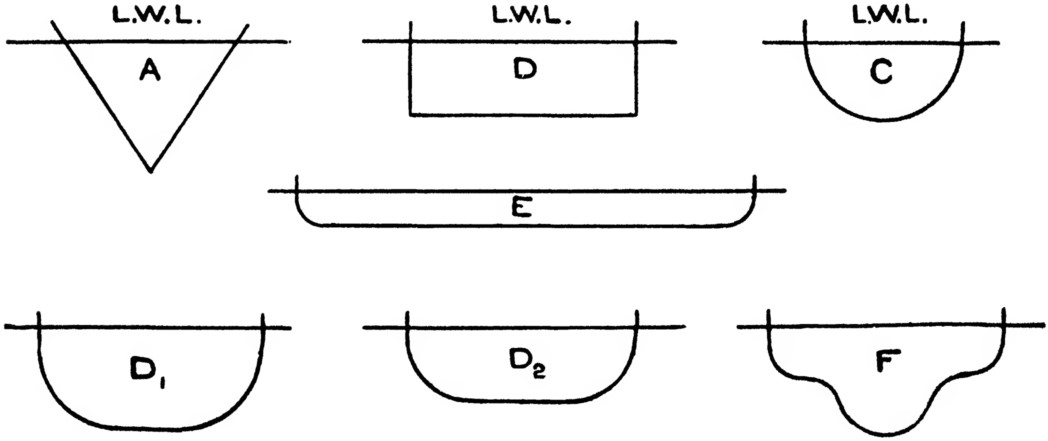


Fig. 7.

It is, therefore, evident that, on the score of wetted surface alone, we should do best with the semi-circle; but, unfortunately, this is a form which has little or no stability.

The triangle has the greatest amount of wetted surface of any of the three forms, and as it is also an unstable form we will dismiss it at once as unsuitable, although a sharp rise of floor is much favoured by many of the American designers.

For stability alone we cannot do better than the rectangle, but here we have the disadvantage of large wetted surface and harsh lines for our boat, if we carry out the angle from end to end.

As all these forms have their disadvantages, we can only make a compromise to get the best results, and this is best obtained by making our immersed mid-section somewhat approaching a flattened semi-ellipse, D^1 and D^2. By this means we get small wetted surface—say, 3.2 to 3.25ft., according to the flatness of the section; and at the same time we have very considerable natural stability without any hard angle to distort the fairness of the design.

These considerations apply to motor boats of all types, as a section of this form is equally suitable for sea or river and for racer or cruiser; although for racing boats we might perhaps more closely approach the semi-circle to save wetted surface, if we can do so without unduly cutting down the stability.

The old "Napier II.," practically a flat-bottomed boat, had an extremely flat section (E), while "Dylan," a very successful Saunders hull, has a bulb keel (F). Both these forms entail a large amount of wetted surface, as also does the double wedge hull to which the more modern boats such as "Panhard-Levassor" closely approximate, but in very fast boats wetted surface becomes subservient to other considerations

Form of Bow.

The next question we have to consider is the form of the bow, and this is largely dependent on the speed and work for which the boat is intended. For a dry, comfortable, sea-going cruiser the water-lines should not be too fine forward, and the sections should be somewhere between a V and a U, with plenty of flare from water-line to deck.

For a racing boat for rough water the bow should be long and fine with easy V sections; while for perfectly smooth water and very high power it may be shovel-shaped to enable the boat to mount on to the surface and skate over it. This principle carried to an extreme has given us the hydroplane, undoubtedly the fastest type of all in smooth water.

The Run Aft.

The run, for a sea-going cruiser, should be fairly fine and canoe-shaped, provided an easy sea boat is required rather than speed; while for the latter quality the run cannot be too flat, as such a form not only prevents the boat "squatting" when at full speed, but also greatly increases the efficiency of the propeller—first, by preventing any air being drawn down from the surface owing to the propeller being well under the flat run; and, secondly, by providing a free run of water to the propeller undisturbed by eddies, etc., from the passage of the boat through the water.

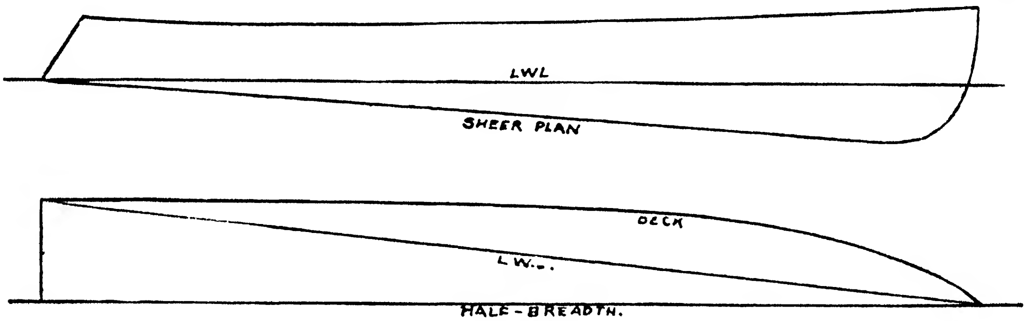


Fig. 8.

An extreme flat stern, while excellent for racing purposes, is by no means a nice type when the boat is going astern or lying to a mooring in a short sea, as it is apt to spank badly and to run under to some extent; it is, however, a necessity on all racers, unless they be of the "Dixie" type.

Form for Racing Boat.

For the moderate all-round boat, with ordinary speed, we must make a compromise of all the foregoing variations of form, as shown in our example; but for the racer pure and simple we must get a long, fine bow, a mid-section which shall combine moderate wetted surface with sufficient stability, and a long, flat run.

To get all these qualities we must give the boat what is known as a raking mid-section: that is to say, her greatest beam at the water-line must be very far aft and the greatest depth of hull well forward. This form is shown car-

ried to the extreme by the accompanying drawing (Fig. 8), in which the bow is a triangle, terminating at the stern, and the run is an inclined plane from the stem to the stern.

Such an extreme form would naturally be hard to drive, owing to the unfair lines caused by the junction of the two wedges; but a modification of this is to be seen in most of the successful racing boats in France and elsewhere. It is a form of hull which is often very bad to steer, especially in a following sea, and it has been carried to greater and greater extremes as the development of high-powered engines of very light weight has increased the speeds attained from 20 to 30 knots. Experience with the "Dixie" boats, however, would seem to show that a hull of a far easier form to drive may be evolved on more normal lines, as shown on another page, but with so much loss of stability as to make the type unsafe for the conditions normally met with in British and European waters, so that it is not likely that we shall forsake the double-wedge form on this side of the Atlantic.

Form for Pleasure Boats.

In the boat for general pleasure purposes, it will be best to have a fairly long bow and flattish run, with an elliptical mid-section, and the greatest beam on the water-line just between six and seven-tenths of the water-line from the stem; while the deepest part should be about four-tenths aft of the stem. These propositions, combined with a curve of sectional areas as illustrated, will give a nice, wholesome boat, which will be easy to drive and dry in a moderate amount of sea.

In conclusion, it must be borne in mind that the object of this article has been, not so much to teach the whole science of naval architecture (which would fill many volumes) as to give a few useful hints to the practical builder who wishes to design his own boats in an up-to-date and correct manner.

It has been the writer's chief aim throughout to be as concise as possible, stating in a few words all the essential points to be considered and omitting all unimportant or abstruse details that could be dispensed with.

Boats in course of construction at the James Taylor Yard, Chertsey.

CHOOSING A BOAT.

Some Advice which may assist the Prospective Purchaser in making a Selection to suit his Requirements and the Means at his Disposal.

Workmanship, Material and Cost.

In choosing a boat, the great thing to bear in mind is that, if one wants a very cheap boat, one should be content with the very plainest finish. It is obviously impossible for any firm to produce a really sound job, combined with high finish, at a very low price, as labour and material must always command their value.

Granted that economies in production can be made by careful purchase of material, and by the judicious arrangement of the details of construction and fittings to avoid all useless expense, still, to build a sound boat, good material only can be used, and bad workmanship should not be tolerated. Consequently, the builder who turns out a cheap, sound job cannot possibly afford to add a lot of brass work and other fittings, unless he is paid extra for them; but his work, even if it be rough, is far preferable to gaudy, unsound stuff. When buying a cheap boat, avoid carvel or smooth planking, as the clench-built or lap-strake boats can be built more cheaply, and, therefore, are more likely to represent good value for a low price. In addition, in a carvel-built boat, if cheaply constructed, all sorts of bad places may be hidden with putty and paint in such a manner that no one without considerable experience would be able to detect them. In the case of a clench-built boat, on the other hand, it is fairly easy to discover bad work, as there should never be any putty whatever in the plank seams, and very little, if any, in the rabbets on the stem, stern-post, and keel

Good and Bad Work.

When the boat is varnished it is very easy to recognise all materials or work, but when the boat is painted it is not so easy, even for those who have had some experience, especially if the boat be well painted. The best test for finding out bad work is to notice the manner in which the plank ends are fitted into the stem rabbet. If the ends be irregular, some fitted closely at the top, and, perhaps, an eighth of an inch away from the rabbet at the lower edge, one may be sure that the work is pretty bad, especially if some of the planks be split by the end fastenings. The scarphs, where the ends of two planks meet, also frequently indicate bad work, and they are a fruitful source of leakage, unless well fitted, as, without shifting the plank, it is very difficult to put a bad scarph right after the boat is built. The grain of the stem and knees should be examined, and any boat where straight-grained wood is used in place of a natural crook should be avoided. Even worse than this is sap, which is very hard to detect in a painted boat, but may easily be seen in varnished work, as it is usually of a lighter colour than the sound oak and looks woolly and rotten when contrasted with the heart wood. In the case of English elm, curiously enough, the sap is generally nearly as good as the heart, and often better as regards strength, if it be close grained and free from shakes, but it is not very reliable on the score of durability. Nor, for that matter, is any common elm, except for use under salt water; the light-coloured wych elm is much better in every way, and should always be used for planking in preference to the common elm. Spruce or white pine is an excellent material for planking clench-built boats, but it should be fairly free from knots, and as straight grained as possible, without any bluish discolorations, which indicate sap. Elm and spruce are the most often used for planking clench-built boats, and, if the wood is fairly free from knots, and sound, the boat should be capable of standing many years' work. The ribs or timbers should be of American elm, and the lighter coloured and straighter grained this is the better.

The Question of Cost.

Just as the belief is frequently expressed, even now, that the automobile is the rich man's plaything, and that a properly built and engined car must necessarily cost several hundreds of pounds, one often hears the half-informed and wholly regretful remark, "Yes, I should like to own a motor launch, if I could only spare three or four hundred to buy her"; or in reply to some recommendation to purchase such a boat, "Oh, no; not for me. Come and talk to me when you can get one for about £20; that's about my figure." Now, were it not that such ideas are so general, it would seem almost waste of time to point out, on the one hand, that little more than half the former sum is sufficient to purchase a handsome launch fairly powerfully engined; and, on the other, that while hulls and

engines are made by British, not Chinese, labour, no motor launch worth the rope to tow her away can be bought new for £20, or anything near it.

A 15ft. Boat.

But to begin at the bottom of the scale, let us suppose you require a reliable boat about 15ft. long or thereabouts for fishing or rough work generally. If so, such a boat, fitted with a good motor of about 3h.p. or so, will cost you, in all, from £45 to £55. Both boat and engine will be rough enough to look at; but in view of the work required from them, there is no need to waste money on appearances. In fact, you will not get them at that price, except at the expense of sound, reliable, and up-to-date construction, so do not expect them. Size up the cost of each detail for a moment, to grasp the facts. Even taking the cost of the motor at £5 per horse-power—and 4b.h.p. is better than 3b.h.p., taking all considerations into account—there is £20 gone. Then call the hull £15 at the least, and you will only have from £10 to £15 for your propeller, clutch, shafting, tank, circulation pump, carburetter, coil, accumulators, a few spares, a pair of oars, and the few other ordinary fittings of a boat. These details all mount up, are all essential, and must be good of their kind to be reliable at all. And when you consider that the average high-grade British or Continental motor costs its maker nearer £10 than £5 per horse-power to build, you will see the futility of expecting much, if anything, in the way of external finish at the low figure.

Boats from 20ft. to 30ft.

Turning now to the cost at first hand of the slightly more elaborate and larger motor-launch from 20ft. to 30ft. over-all length. The motor required to drive a staunchly-built roomy hull of, say, 20ft. or so, 4ft. 6in. beam, and 14in. lowest freeboard—which may be taken as reasonable measurements—will be 6b.h.p., even for a very moderate speed. We may, therefore, allow at least £45 for the motor alone. Properly built, with keel, knees, bedding-timbers, frames, stem and stern plate of oak, lead fittings, mahogany or cedar planking, and mahogany or clear pine decking and waterways, all copper fastened, we cannot expect the hull to cost less than £30, apart from the design. Then there is the bronze propeller and the skeg-piece for the rudder, the shafting, clutch and reversing gear, petrol tank and connections, coil, accumulators, wiring, and a two-way switch, to say nothing of the optional bronze steering wheel: all of which will leave very little change out of another £20. Then side-lights and deck-fittings—few of the latter though there be—a pair of oars, bronze rowlocks, a boat hook, a small folding anchor, and a few fathoms of chain—moorings we may leave out of the question—and five or six fathoms of 2-inch manila, for mooring stem and stern, will in one way and another bring the total well up to £115 as a minimum.

The hull of a 30-footer, again, will hardly cost less than £45, and if built with the plainest fitted turtle-deck cabin forward, for cruising, will probably cost another £10. The motor of, say, 8h.p. may be reckoned at £50 to £60, according to the maker. Adding, then, £35 odd for fittings, as above detailed, we find the cost of a 30-foot motor launch coming well up to £155, which may be regarded as the irreducible minimum for good work. Even so, selection of the engine and all fittings will require the closest scanning of price lists to keep the cost down to that figure.

Running Costs and Upkeep.

The cost of running may be taken at about 2d per horse-power hour, inclusive of lubricant, and, reckoning the price of petrol at 1s. 3d. per gallon, and the consumption at the usual pint or thereabouts per horse-power hour, this works out, for a 30-footer fitted with an 8h.p. engine and running at about 8 miles per hour on the average, at about 2d. per mile as a maximum. For the rest the item of upkeep resolves itself into a question of how much the owner is prepared to do himself in the way of looking after the boat. She will, of course, need to be hauled up occasionally, or brought to bank to have her bottom well scrubbed; but beyond this, and the few shillings weekly for the hire of moorings and her general overseeing, there is nothing to bring the cost of her maintenance, week in and week out, to anything approaching the wages of a chauffeur. For, so far as the motor is concerned, there is little that the careful owner, who studies his engine intelligently, cannot attend to himself, and find additional pleasure therein. Thus it will be seen that a motor-launch, which may even become a floating home, may be secured at a prime cost fully £50 lower, at first hand, than that of a car of the same power, while the expenditure for her upkeep and running, for a whole season, may amount to as much as one-tenth. And if bought secondhand, or, so to speak, created by installing a suitable motor in a ready-made hull, it is difficult to say how great the difference is in favour of motoring afloat from the mere standpoint of relative cost.

Types Suitable for Various Purposes.

General.

Choose your boat to suit the waters and work for which you intend to use her; do not try to adapt a lightly-constructed hull of low freeboard to sea work. Such a boat was intended for up-river use only, and is probably quite unsuited for the sea.

Many boats built for sea work may be used successfully on a river, but as a rule they are too heavy and clumsy for river use.

The old-fashioned long counter should be avoided for any sort of purely power vessel, as it is a most inefficient form of stern, and only adds useless weight and expense to the boat.

The canoe stern is the easiest form of any in rough water, and is all right for moderate speeds, but owing to its sharp rise of floor it is apt to squat badly when the boat is driven at a high speed.

A sea boat may be as highly powered as you like, but her strength of construction and form must be suited to the power of the motor and the speed at which she is to be driven.

For river work choose a light, flat-floored boat with a wide flat run and fairly low engine power. This will give you a boat as free as possible from vibration and wash, with as much speed as you should usually require on a river, where seven or eight miles an hour is quite fast enough, unless there are no small craft about.

Plenty of freeboard and good lifting bow, fine at the water-line, with plenty of flare above, are essential for a fast sea boat. The stern may either be of a canoe shape, an ordinary transom, or a flat slipper stern, but the latter is only suited to very fast boats, and even then, although almost an essential for high speed, is very apt to spank and strain if the boat be going slowly in broken water.

River Boats.

A motor boat, if well designed for river work, must be safe, light, and easily driven with small power; as free as possible from unpleasant vibration from the motor, making little or no wash, and have good seating accommodation on a light draught of water. To ensure safety, the boat should have a good flat floor carried well fore and aft, with a fairly hard turn to the bilge amidships, ending in a flat run, or, for very shallow water, the run may be hollow, with the propeller working in a tunnel, but this greatly increases the expense of construction, and, to some extent, reduces speed. A fair amount of freeboard should be provided, as it is in no way detrimental to speed if not carried to such an excess as to unduly increase the weight of the boat, and its presence greatly increases the safety and comfort without spoiling the appearance if the sheer of the boat be good.

Vibration can best be avoided by the use of multi-cylinder motors, installed on a substantial fore and aft engine bed of ample length, well tied to the rest of the structure, with good, stout floors at frequent intervals.

The absence of wash can only be combined with a fair amount of speed, provided the boat be well designed and of ample length, with a clean, flat run.

Accommodation is so much a matter of individual fancy that it is impossible to lay down any hard-and-fast rules on the subject, but, whether it be arranged in the form of fixed seats or loose chairs, compactness of engine installation will be one of the chief factors to ensure ample space.

Yachts' Launches and other Sea Boats.

The principal qualifications for a good yacht's boat (and they are equally applicable to most sea boats) are safety and sea-worthiness: ample strength to stand beaching at a pinch, or knocking about alongside landing stages; sufficient lightness in the case of yachts' boats or beach boats to enable them to be easily lifted on davits or hauled up on a beach, and, in the latter case at any rate, a well-protected propeller. Freedom from vibration should also be studied, but in this case a strong, simple motor is essential, consequently a slow-running, single-cylinder, two-stroke motor is often preferable, even at the expense of a little extra vibration, as the boat is usually run by absolutely inexperienced yacht hands, who require the simplest possible engine.

Safety, for a sea-going boat of any sort, is the chief consideration, and next to this are comfort and ease of motion in a sea. To combine these qualities we must have a fairly flat bottom amidships, with a sharp turn to the bilge, but the run, though fairly flat, must be rounded up into a modified canoe-type of stern and the bow should be fuller and more lifting than that of the river boat; in fact, a little overhang at each end, if length is no object and the speed is moderate, will help to keep the boat dry in lumpy water.

On the score of strength, a little lightness must be sacrificed to enable the dimensions of the keel and engine bed to be fairly large, and all the scantlings must be of ample strength throughout. A good frame, plenty of substantial fastenings, and sound work should be insisted upon.

Cruisers and Auxiliary Yachts.

The most suitable type of cruiser must necessarily depend on the work for which she is required. We will, therefore, take the three principal types most commonly required—viz., the auxiliary sailing yacht fitted with low motor power, the sea-fishing and cruising motor yacht with a small cabin and perhaps small auxiliary sail in case of accident, and the full-powered motor yacht of more considerable size fitted with high-powered engines and capable of much greater speed than a steam yacht of the same tonnage.

The first of these vessels should be designed primarily as a sailing yacht pure and simple, as she is intended for sailing whenever possible and is only fitted with a low-powered motor to enable her to get home in a calm or to work in and out of narrow harbours where it is difficult to sail.

In such a vessel the motor must be so arranged that it will take up as little as possible of the accommodation, but, at the same time, it must be readily accessible and thoroughly protected from sea and weather. If the boat be small, the cockpit, or beneath it, is the only available place for the motor, and in this case it must be protected as efficiently as possible, either by means of a watertight hatch in the cockpit floor, if the latter be self-draining, or it should

be covered with a suitable casing to keep off all water. With a larger vessel, it is always possible to arrange a proper motor room below, which should be large enough to give every access to all parts of the motor. The propeller must be two-bladed, and so arranged that it can be locked when the blades are in a vertical position in line with the stern-post. It should be of the reversible type and as small as possible consistent with efficiency.

As the motor can be used to help the boat to windward, the draught may be reduced below the limit required for a really close-winded sailing vessel. This reduction in draught, together with the cutting away of all useless deadwood, is of great importance, as affecting the speed of the vessel under power.

Fishing Yachts and Others.

The second type, or fishing yacht, is generally a craft of some 30 to 40ft. only, with a large open well and a whale back forward, which may be extended to a little aft of amidships to form a cabin. Such a boat is not intended to go to windward under sail, and is usually fitted with a snug ketch or lug rig for use with a fair wind. The hull should have plenty of freeboard and sheer, with a good bilge and only a slight rise of floor; both bow and stern may have short overhangs, and should be somewhat of the whale boat or canoe type. In both these vessels ample strength is required for their ordinary work, and they will need little or no extra strengthening for the motor.

The third type of full-powered motor yacht is not so common in this country as it is in the States, but several have been designed recently for various foreign owners by British designers, and the number in home waters, though not large, is increasing rapidly.

In all full-powered motor yachts it is advisable to have twin screws and motors, as in the case of a stop on one motor to replace a damaged plug or valve, the vessel can still be driven at a fair speed by a single motor, or, if anything happened to disable one propeller, the vessel could still reach port under power from the other engine.

Quality and Finish: What to Look For.

In examining a motor boat or any other vessel, the chief points to be noted are: (a) the class of material used, (b) the number and quality of the fastenings, and (c) the quality of the workmanship.

(a) All timber, whether frame, plankings, or fittings, should be thoroughly sound and free from knots and shakes, the keel, gunwales, and stringers should be straight-grained and in one length if possible. Crooked timber of any description, such as the stem, knees, etc., should be cut from natural crooks, in which the grain has a curve as near the shape required as possible.

Planking should be clear and straight-grained, and the scarphs should never be close together in two adjoining planks.

All fastenings should be of copper, if clenched, and of yellow metal in the case of the larger keel and deadwood bolts; screws should be of brass, and all fittings of brass or gun-metal. Locks and hinges, especially, must be carefully examined for iron pins and steel springs, which soon rust.

A good test of the quality of the workmanship in any small boat is the fitting of the plank-ends into the stem rabbet and the regularity of the seams, which should be as small as possible. A large amount of putty in the seams and rabbets should be looked upon with suspicion, and split timbers should not be passed on any account.

Equipment: What is Necessary.

As this is such a very wide subject, we can only deal with those items which are absolutely necessary in a motor boat for ordinary purposes on sea or river.

Every boat should be provided with a pair of stout ash oars or sweeps, with substantial crutches and sockets. A boat-hook, fenders, and an anchor, cable, and mooring lines of suitable size should also be supplied, together with all usual metal fairleads on bow and stern, bollards, flagstaffs and sockets, a tri-coloured lamp for sea work or a set of side and mast-head lights on the Thames will be required if any evening cruising is to be done, but these are frequently treated as extras, and supplied by the owner.

Cushions of some waterproof material should be supplied, and, if desired, they may be turned into life-buoys, provided the stuffing is of some material like kapok, which will float, and yet remain uninjured by water. Pegamoid, Pantasote, or Leverine are all suitable materials for the covers of boat cushions, but if the boat is ever likely to be out in the rain, velvets and silk should be avoided.

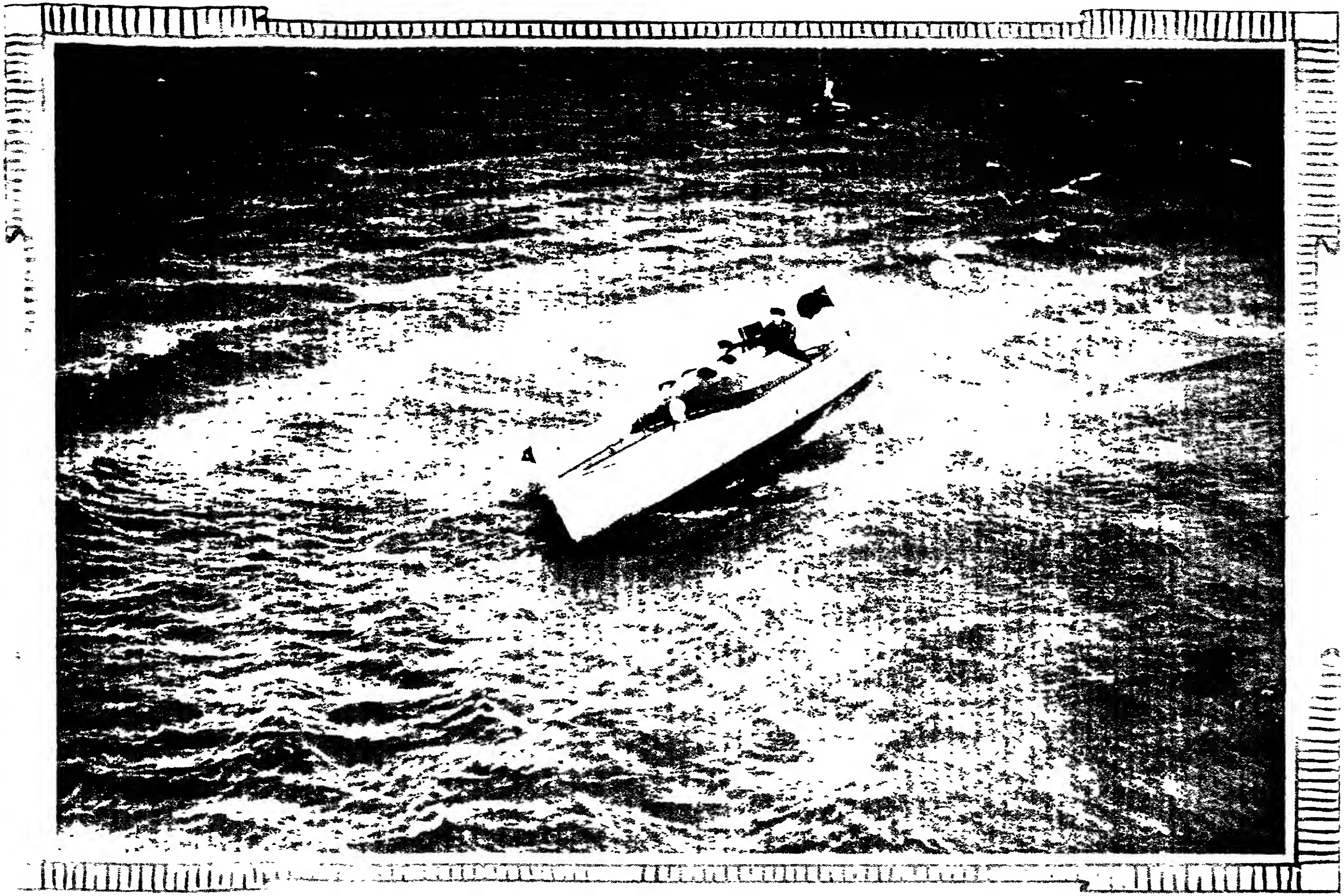
To get a Quotation from a Builder.

If the craft required be a fairly large one, or if it be required for a special purpose, it is better to consult a naval architect, who will be able to deal with the whole matter, including the motor, or who at least would advise as to a suitable design. But if one does not care to do this, and if the boat required is of a usual size and type, any boat builder of repute would be able to satisfactorily meet requirements.

The proper way to get a quotation is first of all to make sure of the local conditions, such as tideway rate, average depth of water alongshore —this can be ascertained from the Admiralty chart—existence or not of weeds; whether the water is usually smooth or broken, and so forth. All these are points which the builder will probably be better able to appreciate than the enquirer can, so to the latter we would say that it will generally be sufficient to name the district for the former to form a pretty correct idea as to

the most suitable type of hull, both as to model and size. Then, having got this, the builder should be asked to quote for clench or carvel, pine, cedar, or mahogany, leaving the scantlings to him. Also get an opinion from him as to the power required. Do not necessarily take his advice as to the make or type of motor; but, knowing the power needed, write for catalogues and prices to those firms who make a speciality of marine motors, and show their confidence in themselves and their motors by advertising them as such. Lastly, remember that while there are many car-engines advertised as marine motors which are suitable enough, there are more which are nothing of the kind. Therefore, don't touch one that does not permit free access to the crank-chamber without taking down the whole box of tricks; nor with any speed above 800 or 900 revolutions—500 to 700 is even better—and, looking mostly for compactness and simplicity of design, don't waste time, but buy it, and send it along to the builder of the boat.

"Gyrinus" racing at Burnham.



"Wolseley-Siddeley," the 400h.p. racer in the Olympic Race, 1908.

The Duke of Westminster is at the helm.

THE CARE OF THE BOAT.

How to Maintain a High State of Efficiency.

Decking an Open Boat.

If the boat is entirely open, and it is thought desirable to deck her forward and aft for sea work, many owners may like to do the work themselves, as it is by no means a difficult job for those accustomed to the use of tools, provided they will be content with a plain canvas-covered deck, and do not aim at producing a regular narrow-planked deck with secret nailing and seams payed with marine glue.

To fit a plain canvassed deck, decide on the amount of round to the beams, and get out a thin wooden pattern or template to the desired curve. Then lay this template on a plank of clear Oregon pine 1in. thick, and mark out the curve of a beam from the template, which should be about a couple of inches longer than the longest beam you will require, about 2in. in width in the centre and 1½in. wide at each end. A good curve for a deck is ½in. to the foot for flat-deck up to 1in. to the foot for a deck with a high "crop." A regular turtle deck may have as much crop as 6in. to the foot, but these decks are more difficult to construct.

Fitting the Beams, etc.

When sufficient beams have been sawn out and planed up ready for use, their positions should be set out on the gunwale of the boat along each side, making the spacing about 1ft. apart. Care should be taken to ensure that every beam shall be square across the boat, and this can best be done by driving a nail into the centre of the stem head, tying a small line to it, and marking on this line the position for the end of the after beam on one gunwale and then marking the corresponding position of the other end on the opposite side by means of the mark on the string. Chalk will show on tarred marlin, or pencil on a chalk line. Repeat this process for each beam, and then cut a dovetail for the ends of the beams for about half the thickness of the gunwale and equal in depth to the beam.

When all the beams have been cut off to the correct lengths and their ends fitted to correspond with the dovetails in the gunwale, they should be fixed in their places by means of a skew nail through the side of the beam, passing through the dovetail into the gunwale. Now fair up the top of the beams by laying a batten over them in every direction and planing the beams down until the batten touches each beam and the gunwales fairly throughout its length. It was for this reason that the beams were cut out 2in. deep, when 1¾in. would have been ample for strength in a small boat, and we would strongly urge the amateur boat-builder to spare no pains in getting the tops of the beams perfectly fair, and if necessary packing up the inside edge of the gunwales to give a fair surface for the edges of the deck to lie on, as any unevenness will only result in a poor job.

Laying the Deck.

The deck may be of ⅝in. match-boarding if it is carefully selected and free from sap or bad knots. It will be best to start with the two centre plan planks, making the joint come on the centre line of the deck so that they can be easily fitted on either side of the stem head, first removing the stem band if there is one. Each plank should be cut roughly to shape and well painted on the under-side, which has the bead on the edge. Then place it in position, holding it tightly in its place with cramps while it is being nailed along both edges and in the centre at each beam. The edges should be marked on top to show the outside edge of the gunwale, otherwise it will be difficult to space the nails evenly. Stout galvanised wire nails will be found to hold better than anything else for this work, unless you can obtain the twisted copper nails, but the latter are rather difficult to get and much harder to drive without bending them. Be sure and drive all the joints up closely before nailing, and afterwards plane the deck off smooth, after punching all the nails below the surface.

Having planed off the deck and trimmed the edges to the shape of the boat, give it a good coat of priming, rubbing it well into all the joints. When this is dry, rub it down and stop all seams, etc., with putty, then give the deck a coat of thick white lead and varnish laid on as thickly as possible. While this is wet take a piece of stout calico sheeting large enough to cover the whole deck, and stretch it as tightly

as possible along the centre line, first nailing it round the stem head and stretching it aft over the deck edge and nailing it down with ⅜in. copper tacks. Now start at the after end and stretch the calico as tightly as you can across the deck and away from the stem at the same time, tacking it about every three inches over the edge of the deck, on to the top strake. As soon as it is evenly stretched all over, the calico should be trimmed off all round and the surface well rubbed down with the hand until the paint underneath shows through all over. It should then be painted over immediately, when the two lots of paint will unite and hold the calico down smoothly so long as the woodwork does not shrink. The edges of the calico must be covered by a ⅜in. half-round moulding of teak, American elm, or other hard wood, and this moulding should be carried right round the boat.

Finishing Off.

The after-end of the deck should be finished off with a ⅝in. teak or American coaming about 3in. high amidships, tapering to nothing at the sides. It should be carefully fitted to the gunwales at the ends and well screwed to the after-deck beam, the joint between deck and coamings being stopped and afterwards covered with a quarter-round moulding in the angle. The calico should be well rubbed down with fine glass-paper as soon as it is thoroughly hard, and again coated with white lead and varnish, the process of rubbing down and painting being repeated at least four times, or until a surface like enamel is produced. The later coats of varnish and white lead should be lightly tinted with a little raw sienna carefully mixed with the white lead to give a rich cream colour. It will be found that this mixture of white lead and varnish not only sticks to the calico better than any ordinary paint or enamel, but it is also very hard and durable, and not liable to crack or blister. The foregoing instructions are for a fore deck with a straight after-edge and coaming square athwartships, as being the simplest form to build. If, however, you are not afraid of a bit more work, the more elegant curved coaming may be fitted by fixing pieces of pine in the angles between the after beam and the gunwales, and shaping them to the required curve, the deck planks being then laid and trimmed to the same shape. A thin wood template should be bent into place and fitted to shape by which to cut out the coaming before it is steamed. If care and patience be exercised the result will be worth the trouble.

Lockers.

Every motor boat intended for pleasure purposes should be well provided with convenient lockers, in which all the various odds and ends, tools, stores, provisions, and what not may be kept, each in its proper place, where it is always ready to hand. Lockers may be of different sizes and so arranged to utilise to the utmost every corner of the boat where there is any spare space. A glance at most motor boats will at once show that very little of the available space is used to the best advantage. A fore peak under the forward deck and a similar locker under the after deck constitute practically all the locker accommodation on many otherwise well-designed and equipped boats, while others, in addition, have a small locker near the motor, containing the batteries.

Where Lockers may be Fitted.

When a boat is built without any sort of fixed seats or side benches whatever, it is, of course, almost impossible to find any place for a locker in addition to those under the decks forward and aft. In most cases, however, there are several fixed seats of some description, and the space under them can easily be utilised for lockers without adding much either to the expense or weight of the boat. Let us suppose, for instance, that the boat has the usual decks at each end and also side benches and one thwart near the engine. The whole of the space under these seats may be shut in with light panelling of ¼in. cedar, teak, or mahogany, to match the rest of the internal fittings. Doors should be fitted at intervals, and the space within partitioned off as may be most convenient.

How they may be Fitted.

Near the engine should be a fairly roomy locker fitted with racks for all the spanners and other tools, all of which should be kept in good order and well greased. The smaller tools should be kept in a case divided into pockets for each tool, similar to the leather tool cases supplied by the motor accessory dealers, but for this work the case should be lined with a flannel throughout, and this lining should be kept in a greasy condition. A plain baize case will do if it is greasy, but it should be kept in an outer case of wood or metal, which should be as nearly air-tight as possible. The tool locker should contain racks for the oil feeders, and a compartment for cotton waste. A box of sundry nuts and bolts, split pins, and other similar odds and ends should also find a place here. It should, however, be borne in mind that each kind should have a compartment to itself—one does not want to hunt for a split pin among a lot of nuts.

The Galley and the Pantry.

One locker should be arranged to hold a cooking stove and a set of cooking utensils, all of which must have their own proper racks, otherwise there will be a constant rattle of pots and pans all the time the boat is running. Next to the locker containing the cooking gear should be one fitted for the glass and table utensils, with a damp-proof box for the knives,

forks, etc. Another may be used for provisions, but for this purpose it must be dry and well ventilated, so the locker under the after deck will probably be most suitable for the larder. Finally, do not forget the wine cellar, which should be fitted with square compartments; and, if space permits, add an ice chest, which will add greatly to the comfort of a summer's cruise or picnic in a day boat, while in a cruiser it is invaluable.

Steering Gear.

The Rudder.

There are few parts of any vessel of greater importance than the steering gear, no matter whether she be an Atlantic liner or a motor dinghy. Inattention to the proper fitting of this portion of her gear has been the cause of endless trouble and annoyance in many a boat which would otherwise have been a source of unalloyed delight to her owner. The most important portion of the steering gear is undoubtedly the rudder itself, and in a motor boat there are many points to be considered before deciding which is the best type to use. We may roughly divide the motor-boat rudders into two broad classes, viz., those hung on a rudder post with a heel bearing or pintle, and those which merely hang below the underbody of the boat without any external support whatever. The first type is usually found on the smaller motor boats of the dinghy and yacht's cutter type, and also on most auxiliary yachts and motor trading vessels, but they are by no means confined to any particular class of boat. They are most suitable for use on vessels where strength rather than high speed or quick turning is the chief end in view. There is no doubt that this type is the strongest and least liable to injury, but against these good qualities we must put the extra weight and resistance of the rudder post—usually of galvanised iron or bronze—and also the extra strain on the steering gear caused through the pressure on the rudder blade being entirely abaft the centre of the spindle or rudder stem. The second type of rudder is always to be found on all modern high-speed boats in which the afterbody is flat and without deadwood, not only because it offers considerably less resistance than the older type, but also because it is the lightest possible form, and, when properly balanced, it is much easier on the steering gear than any other. Of the many varieties of underbody rudder, we may take the slightly-balanced single-bladed rudder hung abaft the propeller as being at once the simplest and most suitable for general use on all sorts of high-speed boats although there are many other varieties. Before leaving the subject we would point out that it is very easy to get too much balance on a rudder, which causes the helm to fly over to one side if left alone when the boat is travelling at any considerable speed. This is especially noticeable when the rudder is very close to the propeller and not so far below the boat, for the spiral column of water from the screw strikes the fore edge of the rudder on one side and tends to turn the boat round. To remedy this defect one can either remove some of the balance, or place the centre of the rudder slightly out of line with the propeller and tail shaft. An extremely deep and narrow rudder is not so liable to this trouble, but it causes a fast boat to heel over very considerably if it is put over sharply, and it is also weak on account of the great leverage at the point where the stem enters the boat.

The Rudder Head Gear.

Whatever form of rudder one may decide on, it is most important that the actuating gear on the rudder head should be thoroughly efficient, although this is a point which frequently appears to be much neglected. There are four methods of transmitting the motion from the helmsman's hand to the rudder:—

(*a*) The direct tiller, which is naturally the simplest and most efficient, where the helmsman is placed close to the rudder and the size of the vessel is small, but it is unsuitable for large or very fast vessels.

(*b*) The same tiller connected to a wheel in any suitable part of the boat, by means of wires and leading sheeves. This form is very suitable for ship's or yacht's boats, in which the steering is sometimes done from the stern and at other times from amidships, but great care must be used in fitting the leads in order to prevent the wires from becoming slack when the tiller is hard over, and tight when it is in its normal position, or vice versa. This trouble can easily be avoided by the use of a sliding sheeve on the tiller, fitted with a pair of eyes, to which the wires are attached; then, when the tiller is put hard over, the sheeve slides forward towards the end of the tiller, and thus increases the power as the strain increases. Even with this slide there is usually considerable backlash in the wire, but on the other hand it is a simple and inexpensive fitting, and is not likely to get out of order. The wires may be connected with a wheel in the usual manner, or they may be simply attached to a vertical lever fitted near the engine in any convenient position.

(*c*) In place of the tiller, a cross yoke is often used, but this is not a good arrangement, as it has not only all the objections to be found in a tiller, with a considerable increase of backlash as a rule, but it is also liable to jam hard over and lock when the boat is going full speed astern. A yoke on the rudder head connected with a second yoke and tiller near the engine is occasionally seen; it used to be a very common form of steering gear in the older forms of sailing canoes, but it is not at all suitable for motor boats.

(*d*) The fourth and most efficient form of

rudder-head fitting for all motor vessels which steer with a wheel amidships or forward is the grooved wheel on the rudder usually to be found in most modern motor boats of any considerable size. This wheel is keyed on to the rudder head or stem, and the steering wires lie in the groove, the centre of the wire being attached to the wheel at the after part by passing it through two holes in the groove and round a spoke, to which it is seized. The forward ends of the wire are taken to the steering wheel, which may have either a vertical or horizontal axis, according to taste. All the sheeves over which these wires are led should be of ample diameter and of galvanised iron if the boat is for salt-water use, as brass sheeves soon rot the galvanised steel wire.

The Wheel.

Steering wheels are of two general types, viz., the regular ship's wheel with a horizontal axis, and the more modern motorcar wheel with a vertical axis, which is now usually fitted in motor boats with any pretensions to being up-to-date. One advantage of the vertical shaft—that being the one usually fitted on sea-going boats—is that it occupies less space than the horizontal type which is used mainly for river work. The old form of wheel was no doubt most suitable in the days when large vessels were steered by hand power alone, but not only does it require more learning, but it is seldom as sensitive as the horizontal wheel with the vertical spindle. With the latter form all the novice has to remember is to turn the wheel in the direction he wishes the boat to go, and this is far easier to think of if the wheel turns horizontally in the same plane as the boat than it is when the wheel turns in a vertical direction and the boat turns in a horizontal direction, although in both cases the wheel actually turns to the same side as the boat goes.

Covering when at Moorings.

Exposure to weather causes great deterioration to the boat, especially with regard to the paint and varnish. The evil is aggravated where the boat is likely to lie under trees or exposed to coal dust, drift sand, or other sources of gritty deposit, to say nothing of the paper and other rubbish which may be blown or thrown into her.

River Requirements.

A cover of some sort is naturally the best cure for this evil. Where the boat is kept alongside a river bank, a complete waterproof cover, with side curtains sufficiently deep to just clear the water, can be laced tightly over the boat each time she is put away after use. Certainly the trouble of lacing and unlacing a cover of this sort is considerable, to say nothing of its weight and unwieldy nature if one has to do the work single-handed, but, if properly made, such a cover will nearly double the life of the boat, and is well worth the extra trouble it entails.

The cover for a river boat should be made of stout Willesden or Birkmeyer canvas, carefully fitted to the boat, with openings at the bow and stern for the mooring lines to pass through. It should be cut so as to fit over a ridge pole extending from end to end of the boat and supported on light X crutches from the bottom or seats of the boat. The sides should fit closely to the boat and should have a loose draw-string all round to keep the lower edge tight to the planking if the shape of the boat will admit of this arrangement. A boat with a sharply raking slipper stern cannot have a cover kept tight with a draw-string, as it would be continually working up the slope of the stern. In this case, therefore, the owner must have either lashings passed right underneath the boat's bottom or else one must trust to some small pieces of lead to keep the sides down.

Covers for Sea Boats.

The cover of a sea boat should always be arranged in such a manner that a man can safely and easily get aboard when the cover is in place and be able to cast off or secure the moorings without disturbing the cover. Such a cover may either be made of the same material as suggested for the river boat, or it may preferably be of regular sail coat material, i.e., canvas dressed with linseed oil, white lead, and soft soap, or some other approved sail cover dressing which will render the canvas perfectly waterproof, without making it too stiff to handle and fold up for stowing away in a locker while under way. It would be difficult to rig up a ridge pole in a boat jumping about at moorings, so it will be better to have a flat cover with a series of split bamboo battens placed in transverse pockets across the cover about 3ft. apart and resting on the gunwales when the cover is in place. The sides of the cover should only overlap the gunwale by about two or three inches, and they should be fitted with good-sized eyelets, to lace down to a series of stout hooks placed just under the rubbing band. The use of hooks instead of eyes is a great point, as they save all the labour of removing the lacing each time the cover is put on or taken off. With hooks, the loop or bight of the lacing between each pair of eyelets on the cover can be slipped over the hook on the boat, and when all is in place the lacing can be hauled taut and made fast at the stem or stern. For mooring purposes a piece of the cover over the mooring bollard should be in the form of a loose flap, or else there should be a large opening in the cover to give free access to the bollard and fairleads.

If a boat has to be laid up in the open or in a shed consisting of a mere roof without sides, something more than a canvas cover should be

used. A winter cover can be cheaply made of ½in. match boarding secured to a light strip of spruce bent round the boat and the whole covered with tarred felt.

If the boat be an open one with no fittings projecting above the level of the gunwale, this cover may be flat, but if there be a cabin or other non-removable fitting the cover may be arranged as a pent roof with the ridge fore and aft. In this case it will simplify handling if the two sides be hinged along the ridge, taking care, however, that the joint is adequately covered with felt, but in such a way as not to prevent the two sides being folded together.

Awnings.

For Open Boats.

The simplest form of protection from the sun is the plain canvas awning, consisting of a piece of Birkmeyer or Willesden canvas made of the same shape as the portion of the boat which it is intended to cover. If the awning is to be carried on single stanchions at each end, as is frequently the case, some means of extending the canvas transversely must be employed This is usually accomplished by inserting flat cross battens of light wood or split bamboo in pockets sewn on the canvas, then, by the use of light cords from the ends of each of the battens to the gunwale of the boat, the whole awning can be kept level and prevented from lifting up at the sides when caught by the wind. This form of awning can also be used as a boat cover by lowering it down on the deck and lashing the cross battens to the gunwales. It also has the advantage of requiring only the two end stanchions, and of being easily stowed away in a small space when rolled up snugly round the cross battens. On the other hand, it has the great disadvantage of sagging down into a hollow amidships, unless a very considerable strain is used to stretch it fore and aft, although this can be removed to some extent by the use of a light wire running under the battens from stanchion to stanchion, and from them to the deck at each end, where it is set up as tightly as possible by means of a pair of rigging screws. Even when stretched as tightly as possible, the best that can be made of it is a flat surface, which will allow the water to collect and possibly soak through in rainy weather, unless it is dressed with some heavy oil or paint dressing, which again will be a great obstacle to making it up into a small roll for stowing away when not in use. One of the best possible arrangements for a canvas awning, if the expenditure of some little time in putting it up is not a great disadvantage, is one fitted with a central bamboo ridge pole extending between the two end stanchions over which the awning is laid, and the sides extended on flat transverse battens as before; but in this case the cross battens should be steamed to a curve so as to give the whole awning an arch capable of shedding any amount of rain. If, in addition to the arched cross battens, the canvas is dressed lightly with a couple of coats of linseed oil, mixed with a little white lead, it will be quite impervious to wet.

Awnings for Larger Boats.

When it comes to dealing with motor yachts of any considerable size, one probably has to do with a vessel provided with masts of some description, which greatly simplify the arrangements required for the awnings. If, in addition to the masts, the vessel is large enough to have fixed on her bulwarks stanchions and rails high enough for the sides of the awnings to be laced to them direct, one can then fit a regular awning with a good pitch, similar to those in use on large steamers. In this form the awning has a stout ridge rope down the centre, to which at intervals are attached a number of lines, with their ends meeting in the centre a few feet above the ridge rope, and forming what is known as a crow's foot, which is kept taut by means of a couple of lines to the masts so arranged as to give a considerable upward pull. The sides of the awning are then laced out taut to the rails or wire ropes running through the stanchions on the bulwarks. The best form of crow's foot consists of a small vertical piece of hardwood full of holes, through which the various lines suspending the ridge rope are run, and thus free to adjust themselves to the various strains along the whole length of the awning. An awning of this description can be suspended from a single mast, provided there is a strong stanchion to take the pull at the other end, but in this case the lines forming the crow's foot require very careful adjustment.

Painting and Varnishing.

Cleaning Off Paint Work.

Before the boat is repainted or revarnished at the beginning of the year the whole of the woodwork should be cleaned off thoroughly, and all the seams, etc., carefully overhauled as regards the condition of the caulking and stopping. If the boat is varnished it will be easy to ascertain the condition of the seams without removing the varnish, and if they are in good condition all that need be done is to clean and rub down the existing varnish before applying the fresh coats. This may be done by scrubbing the whole boat with a strong solution of Hudson's extract, or with soda and warm water, to remove the dirt, finishing with clean rain-water to take away all traces of the alkali, which would spoil the

new varnish if any of it remained on the wood. If the existing varnish is in a bad state, blistered, or discoloured, it will be best to remove it entirely by the use of one of the many detergents on the market.

The Use of Detergents.

When using a detergent be careful not to get any of it on your hands or clothes, as many of them cause a severe burn, although there are now some preparations which are quite harmless in this respect, while retaining the full powers of the old caustic soda and lime mixtures so far as the removal of paint is concerned. Caustic soda and quicklime used to be the favourite paint remover in the early days of yachting, and is known as "soodgee-moogee" in the language of sailor-men. Another great objection to the old style of paint removers was their tendency to stain the wood if they were allowed to stay on too long, and also the difficulty usually experienced in removing all traces of alkali before the new paint or varnish was applied. A good wash of strong vinegar and water will neutralise most of these preparations, but this in its turn must be washed off thoroughly with soft water.

Rubbing Down.

When the surface to be painted has been thoroughly cleaned, either by washing or by the removal of the old paint or varnish, all nail-holes, cracks, and seams that require it must be carefully stopped with putty, which, in the case of varnished work, must be coloured to match the wood. As soon as this stopping is hard the whole surface of the boat must be rubbed down with either fine glass-paper or pumice-stone and water. If the old varnish is in good condition, pumice-stone powder and water alone will be sufficient to clean the surface and to rub it down at the same time; but with hard paint the solid pumice-stone must be used, finishing off with the finest glass-paper or pumice-powder. If a boat is to look really well, too much labour cannot be expended on preparing a perfect surface for the varnish, as on this depends most of the excellence of the result. By the way, do not forget that if there are any holes, etc., to be stopped the places must be given a thin coat of varnish or paint as the case may be before the putty or stopping is applied, otherwise it will not stick to the old paint or wood properly. The above instructions are chiefly applicable to varnished work, but will usually apply to paint-work as well unless the latter is in a very bad state, in which case it will be necessary to burn off the old paint with a blow-lamp, or else to scrape it off. When scraping woodwork great care must be taken not to scratch the surface, or it may be difficult to get the marks out again without planing up the whole boat.

Varnishing.

Varnishing is an art which is little understood by many of our coast boat-builders, and still less by the ordinary yachtsman. To see it at its best we must go to a coach builder or to some of our best Thames boat-builders, although even of these there are only one or two who are superlatively good. Varnish should not be applied in a hot sun, although moderate sunshine is beneficial. Again, it must on no account be done in frosty weather, unless it is in a well-warmed shop, as frost will ruin any paint or varnish when drying. Paint does not require so much care as varnish, and should be applied in thinner coats, equally well rubbed in, the final coat being composed of white lead and the best varnish, tinted to taste, except for black and dark-coloured boats, for which some of the various enamels are best. The usual instructions as to varnishing are to take as little varnish as possible on the brush, and to lay it on as thinly as possible on a perfectly dry surface. The correct method, however, is to first carefully wipe over the work with a damp chamois leather, and then apply the varnish as quickly as possible. The varnish should be applied fairly thickly, and worked backwards and forwards until the brush almost sticks to the surface. A quantity of whiting should be used on the glass-paper when rubbing down each coat. This whiting will fill up the pores in the former coat, whilst at the same time preventing the glass-paper from sticking to the varnish, and the rubbing over with a damp chamois leather will remove every particle of dust remaining.

Several of the enamels now on the market are very good for boat work, but our experience has been that for light colours a white lead and copal varnish paint is the most durable and easily applied of any.

It is very false economy to use anything but the best paint and varnish on a boat; inferior paints soon change colour or blister, while poor varnish turns white or "blooms" directly it gets a good wetting.

Gilt Work.

The appearance of any boat is greatly improved by a gold line round the top strake; and, in certain cases, by a small amount of gold scroll work at the bow and stern. The worst of it is that many people never know where to stop when they once start gilding, and simply plaster the whole boat with florid and inartistic gilt mouldings and masses of ornament frequently without either taste or design, the effect being merely tawdry and vulgar.

In painting a motor boat, as in every other form of decoration, good taste is essential, and it is easy to sum up the owner's sense of the fitness of things by the way in which he has his boat gilded. Therefore do not overdo the gilt-work on your boat, and remember that for sea work even less is permissible than on the river.

The general practice for yacht's launches and other small sea boats is to have no gilding beyond a narrow gold line about 1in. above the

lower edge of the top strake, without any scroll work at either end, except perhaps a spear-head to finish off each end of the line. For a 25ft. boat the line would be only about ⅝in. in width, and it should be in a slight hollow worked in the plank, which greatly enhances the effect by catching the light at all angles and at the same time protects the gold leaf from injury. For a river launch the gold line may be supplemented by the addition of a neat and artistically-designed scroll at bow and stern, provided the scroll is small and simple in character.

The Boat's Name.

It is also necessary to have the boat's name on both bow and stern to comply with the Thames Conservancy regulations. The gilt work can therefore be so arranged that it does away with the abrupt ending of the line at the name by means of a very small bit of scroll, and a slightly larger scroll may also be placed between the name and the stem, and at each end of the name if it is on the transom of a square-sterned boat. While on a round or canoe stern the name, being on each side, can be treated in the same style as it is on the bows, but with slightly less ornament. Many owners of river boats, especially if they are yachtsmen, prefer to keep to the simpler and quieter fashion of the sea, and only have a plain line and the boat's name without any flourishes.

Working a Gold Line.

Having decided on the width of the line and its position on the top strake, get a square batten or strip of wood long enough to reach from end to end of the boat. This batten is then lightly tacked to the top strake just below the lower edge of the line, care being taken that it is perfectly fair with the sheer. A ⅝in. round-soled plane should now be borrowed. (We say *borrowed* advisedly, as many copper nails are likely to be met with, and these have a certain effect on the plane which one would prefer not to see on one's own tools.) All nails which come in the line having been punched home about ¼in., the hollow line can be cut with the plane, using the upper edge of the batten as a guide, and finishing off the ends with a small flat gouge, the whole being well rubbed down with glass paper of various degrees of fineness wrapped round a piece of wood cut to fit the hollow.

When the hollow is finished as smooth as possible it must have a coat of paint or varnish, as the case may be, and when this is dry all nail holes, etc., must be carefully stopped and the hollow again rubbed down and coated until a perfect surface is obtained, matching the rest of the boat. As soon as the last coat is dry, the hollow and all the surrounding surface must be thickly dusted over with whiting to prevent the gold leaf sticking to the rest of the paint or varnish. Now, with a fine brush and a steady hand, give the hollow a coat of gold size and chrome yellow laid on as smoothly and with as clean an edge as possible. When this is "tacky" or just beginning to dry, lay on the gold leaf either with the proper flat brush used by gilders, or, if it is a windy day, by means of waxed paper, on which the leaf may be bought ready for use. The latter method is the easiest for amateurs, but the other way produces rather better results. When the gold size is dry the gold line may be polished gently with a soft camel-hair brush, which will remove all superfluous gold leaf and leave the line clean and smooth. On no account touch the gold until the gold size is dry, or you may spoil it unless you have had considerable experience.

Anti-Fouling Composition.

One of the principal elements of speed, especially in motor boats of moderate power, is a smooth bottom coated with some preparation which will prevent the growth of weeds and barnacles. Unfortunately, owing to the trouble and expense of hauling a boat up, and rubbing her down and recoating her, whenever she is inclined to get a bit foul, many boats are allowed to get into such a state that their speed is seriously decreased. Probably no composition will absolutely prevent fouling for a whole season, as those compositions which are most efficient in preventing the growth of weeds, etc., usually owe their efficiency to the fact that the surface is always wearing off or exfoliating and thus exposing a constantly fresh, clean surface to the water. Naturally, this wearing away of the surface must end in the disappearance of the composition after a few months' use. Another objection to some of the earlier compositions was their rough surface after a short exposure to the water, and as a smooth surface is most important, this was a serious disadvantage. Copper sheathing is one of the best surfaces obtainable, as copper not only exfoliates in salt water, but it also keeps its smooth surface if the boat is in constant use. Even copper, however, must be scrubbed once or twice in a season, and it is not so good in fresh water as in salt.

Coating the Bottom.

If it is important to obtain a perfect surface on the upper part of the boat for painting and varnishing, it is ten times more important for the under-water surface, as on this depends much of the speed of the boat. Therefore all the bottom must be rubbed down, stopped, and coated with the best paint, until the surface is as smooth as glass, and as this surface has to stand the constant action of the water, ample time must be allowed between each coat of paint to ensure the previous coat being perfectly dry and hard. Once a perfect surface of this sort is obtained, it is not difficult to keep in good condition, but it should be looked at once or twice during each season and any bad places touched up. On this paint surface the anti-fouling composition should be carefully laid in accordance with the maker's directions, which vary with

different brands, the principal makes being Holzapfel's, Blakes' Algicide, and Jesty's compositions. Copper dust laid on varnish is not only a first-rate anti-fouler, but it has also an excellent surface like blacklead. To apply it, first turn the boat bottom up and give her a coat of the *best* varnish over the paint surface, and as soon as this gets "tacky" pour the copper dust all over it, sweeping it gently to and fro with a large soft brush until no more will stick to the varnish. Two coats of this preparation should be applied, with an interval of 24 hours between them.

To Pot-lead a Boat's Underbody.

For racing purposes a boat is often blackleaded. Almost every yachtsman has his own methods and ideas, but these may generally be narrowed down to two; the first one being to mix the desired amount of pot-lead with enough thin shellac to give it a syrupy consistency, applying the mixture with a soft brush and rubbing it with a cloth after it dries. Sometimes dry graphite is dusted over the varnished coat before it is quite dry; when, if the resulting surface be not perfectly smooth, a light "going-over" with very fine sandpaper will produce the desired result. The second method—and perhaps the more satisfactory—is to varnish the hull with shellac mixed in alcohol, so as to give a "tacky" surface. On this, graphite is dusted through a muslin bag before the shellac is dried. When dry, the surface may be rag or brush polished. In this way, small areas may be treated at a time, or one man may varnish while another follows up with the dusting-bag, so that the different coatings do not have a chance to dry before the graphite is dusted on.

Sundry Advice.

Remember that a smart appearance counts for much.

All brass work must be cleaned every day if it is to look well, and nothing looks so slovenly as dirty brass work. If it cannot be kept up properly, it is better to let it turn black and then varnish it, when it will become a dark bronze.

If the flooring is covered with linoleum, it should be varnished to preserve it and to keep it clean. Gratings should not be varnished if it is possible to keep them scrubbed, but they must be scrubbed every day or they will turn black.

Do not attempt to patch up shabby paint work with a few brushfuls of paint here and there on the worst places. The result will only show up each bit of new paint with great clearness; it is better to give the boat a coat all over at once and make a job of it.

If the boat is to be painted outside, she should be thoroughly stopped and rubbed down with two or three coats of priming until a good surface is obtained, then give her two coats of the intended colour made by mixing pure white lead and the best copal varnish and tinting to taste for the finishing coats.

All varnish and paint work should be most carefully cleaned every morning with a chamois leather, and in the case of varnish, a lick over with a brushful of varnish should at once be given wherever there is the slightest sign of a bare place, otherwise the wood will soon turn black or grey, and it may be impossible to put it right afterwards. This is especially the case with oak.

"Fiat," a 200h.p 8-metre racer that competed at Monaco in 1907.

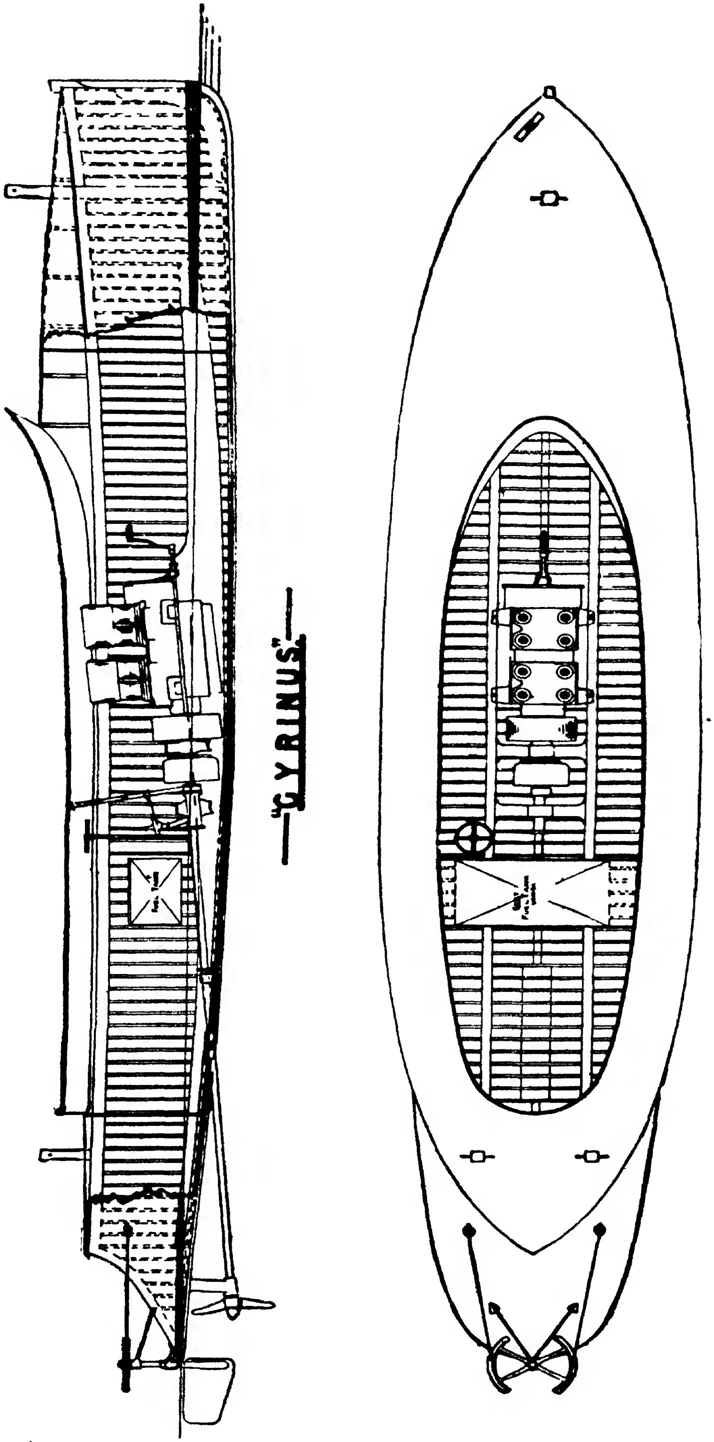
DESIGNS.

An 8-metre Racing Cruiser.

This boat was launched during the 1908 season, having been built to the M.Y.C. restricted class, or 8-metre international racing cruiser class as it afterwards came to be called. She was fitted with a Thornycroft four-cylinder motor of 4 5/32in. bore (106mm.), developing about 40h.p., and she attained a mean speed of 20.092 knots in a measured mile trial, and on more than one occasion averaged 19½ knots right through a race. She was certainly the fastest boat of her class, and though the next season will no doubt see her performances eclipsed, she must be considered one of the most remarkable fast launches of her time.

Her length is 26ft., beam 5ft. 4in., freeboard amidships 1ft. 7in., draught amidships 8in , extreme draught 1ft. 7in., and displacement about 17cwt. The hull is of ⅜in. cedar, with steamed American elm frames. The stern deadwoods, floors and tube chock are of English oak. The design closely resembles an earlier Thornycroft boat, "Scolopendra." The latter was a 30-footer, and "Gyrinus" may be regarded as the same hull with 4ft snubbed off the bows. The bow in consequence looks extremely bluff, as indeed it is near the deck line, but she is intended to lift to the curve of the forefoot at full speed and she may then be regarded as a 30ft. boat that lifts the first 4ft. of her length when running. The 'midship section is a flat U, which form is extended remarkably far forward, while aft the sections become flatter and flatter. The stern is of the "beaver tail" form and not extremely wide. As already stated, the maximum beam is 5ft. 4in., but on the water line it does not much exceed 4ft., the extra beam required to bring the boat inside the class rule being made up in flare. The hull is a direct contradiction to the double-wedge type so favoured abroad, but it is certainly an extremely easily-driven form, and on more than one occasion proved capable of being driven at full speed in a very nasty sea. The boat is decked in fore and aft and provided with watertight bulkheads, and, to improve her sea-going capabilities, the side decks are fairly broad, giving a narrow cockpit, which is surrounded by a rather high coaming. She has very light timbers spaced about 3in. apart, and the engine bearers run the whole length of the boat, making her very stiff; further, it should be noted that the engine is installed, fairly far forward, on a slant, being coupled direct to the propeller shaft without any universal joint. The clutch has no spring, being held in engagement by the thrust of the propeller.

The beaver tail stern made the rudder arrangement rather difficult; it has, however, been got over as shown in the illustration, the lines being taken through the stern to the wheel, which is mounted on a beam athwart the cockpit, this beam helping to stiffen the boat considerably. The design was by Messrs. J. I. Thornycroft and Co , but the boat was built by Maynard, Chiswick.



"CYRINUS"

"Dixie." A 40ft. Racing Boat.

We now have an example of an out-and-out racing boat built without any restrictions whatever except a 40ft. limit of length. The type differs materially from the accepted British and Continental forms, but is a very favourite one in America, and for pure ease of driving is probably as good as any that can be devised. The salient features of this very beautiful design are small beam, round bottom, and fine ends. So far as the bow is concerned, the fineness is nothing abnormal, at any rate below water, but her stern is very different from that generally adopted in the fastest motor boats in this country and in France. No doubt it is a beautifully clean run, but whether it is the best form for very high speeds is open to argument, especially in the case of a boat intended for a heavy engine Probably such a stern is excellent for a moderate-powered boat, and especially when there is ample stability owing to low engine weights and a fair amount of beam, but in "Dixie" we have very little beam and very high engine weights; consequently her fine stern—while it may be very easy in a sea—does not help her much in the matter of stability, especially as she has an unusually barrelly type of middle body. That this is no mere surmise is proved by her well-known crankness. But for smooth water work we doubt if the design could be improved upon. A point to which we would like particularly to draw our readers' attention is the beautiful fairness of her lines, and especially of her sections as shown in the body plan; although they may be wanting in stability they are perfect of their kind, with the most harmonious changes from bow to stern. Here are no sudden transformations of a V into a flat, or a circular bottom into a wall side with an abrupt flare on the extreme top, as we find in so many racing motor boats, but everywhere the lines are such as must please the most fastidious naval architect accustomed to yacht work. Given more stability by means of lower engine weights and extra beam, we have in "Dixie" a far more serviceable type of boat than that evolved by the designers of most of the successful European racing motor boats of high power, but it is to be feared that lower engine weights are impossible with the power required, and more beam would seriously interfere with speed, so that for the exacting conditions of English and French racing the double V type is probably the best, and likely to be retained.

Single-handed Motor Cruiser "Louise."

This little cruiser has proved herself a most able boat for single-handed work, and her extremely light draught enables her to cruise in shallow waters, where an ordinary cruiser of her tonnage would be unable to go unless fitted with a centreboard. Contrary to expectation, she has proved a very able little boat to windward, and for general sea work, being fast under sail, and her speed under power only is over 5½ knots. She is fitted with a small two-cylinder Fafnir engine, placed in the cockpit, with a casing over it which forms a seat. The cabin has ample room to sit upright on the sofa berths. The latter are of full length, and 2ft in width. Forward of the cabin is a fore peak, containing the cooking stove, and a large store cupboard or pantry. There are also several other large lockers aft She has a sloop rig with lowering mast, and the mast being fitted in a steel tabernacle or case on deck, does not interfere in any way with the accommodation below. A boat of this type is very well suited for use on the Norfolk Broads, or for any shallow estuaries, and "Louise" has twice made a passage from the Thames to the Isle of Wight, which is no light undertaking for so small a boat.

Her leading dimensions are: Length o.a. 25ft , l.w.l. 20ft., depth 6ft. 1in., and displacement 2 1 tons. The lines are very pretty and the canoe stern looks extremely well in a boat of this type. She could easily be run single-handed if necessary, though her accommodation is ample for two people Small and inexpensive, she represents a type of little week-end cruiser within the means of almost any one The upkeep would be very small indeed, and before long we expect to see a great many such boats about. Messrs. Linton Hope and Co. are responsible for the design

A Small Clyde Cruiser.

This interesting little cabin cruiser "Iola," the designs of which are by Mr. C. L'Estrange Ewen, 45, Hope Street, Glasgow, and which appear herewith, was built early in the season of 1908 at Tighnabruaich for a well-known Clyde yachtsman. The leading dimensions of the boat are 32ft. on the water line by 7ft. 7in. beam and 5ft. 4in. in depth from the top of keel to underside of deck. In the designing of "Iola" speed has taken second place to comfort and seaworthiness, with the result that she has been given good freeboard, beam and draught and a handy auxiliary rig—all necessary features in a boat which is expected to cruise in all weathers. The speed obtained is nearly seven knots, although only 10h.p. is installed. A small auxiliary sail plan consisting of mainsail and jib is provided, giving a sail spread of 226 square feet, and this has been found ample by the owner when he has desired to use sails The accommodation of the vessel starting from forward gives a roomy forecastle with excellent accommodation for one man and his belongings, together with the usual chain locker, stowage places and galley and cooking utensils. It may be of interest to note that so easily is a cruiser of this type handled that the owner has not yet found it necessary to ship a paid hand. The main cabin is situated amidships and is divided from the forecastle by a bulkhead and sliding door. The forecastle may also be entered from the deck through a hatchway. The cabin has full standing headroom under the skylight and ample locker and other accommodation, and provides excellent sleeping berths for two. In the centre of the cabin a folding table is fitted for use during meals. From aft, the main saloon gives access to a passage way communicating with the engine-room, on the starboard side of which accommodation has been found for a roomy lavatory, while on the port side is a hanging place for oilskins or other clothes. Another convenient fixture also finds space in the passage way in the shape of a commodious chest of drawers, this being a very necessary feature which is only too rarely found on these small boats. Aft of this passage way the engine-room is entered through a sliding door, and the space here given is very ample, giving every access to all parts of the motor and accessories, whilst at the same time providing excellent seating accommodation, with tool cupboards and lockers for spares. The power installed is a 10h.p. paraffin motor fitted with reverse gear and solid propeller. The engine exhaust is carried to the deck and thence to the funnel, which is placed amidships. The cockpit is entered through a pair of folding doors aft, and here seating is provided for six persons. Since launching the boat has been in constant use and has made extensive cruises, not only on the Clyde but throughout almost the entire length of the west coast of Scotland, where at times she has been subjected to exceptionally severe weather and has acquitted herself in a way that has won the approval of the most prejudiced sailing men.

Shallow-draught Passenger Vessel.

This vessel was designed for passenger service in the Adriatic, where shallow draught is a necessity, while at the same time the vessel must be able to face a certain amount of sea occasionally. She is a steel vessel 70ft. in length by 14ft. beam, with a modified tunnel stern, and is from the board of Messrs. Linton Hope and Co. She has a cargo hold forward for passengers' baggage and a small amount of general cargo. Forward of this is the crew accommodation under a raised forecastle, with a water ballast tank for trimming when the hold is empty. Aft of the hold there is a spacious engine-room with steel floors and large engine room skylights, and abaft this again the officers' quarters, together with a large store room On deck there is a cabin forward with accommodation for 25 passengers, but as she is only intended for short trips there is no sleeping accommodation for the passengers. The cargo hatch between this cabin and the raised forecastle gives access to the hold, a small derrick being fitted if required on the short mast for working the cargo The roof of the saloon is carried right aft, forming a shade deck; this shade deck is carried out to the rail of the vessel, forming a shelter on each side of the saloon. The line of this roof is broken by the pilot house, which is raised some 3ft. above the roof of the saloon. The pantry and galley is placed on the port side, opening into the saloon, and there is the usual lavatory on deck. Aft of the pilot house is a funnel, which contains the exhaust silencers, and two large ventilators are fitted in the engine-room skylight. Alternative plans have been submitted for fitting this vessel either with a single four-cylinder 60h.p. Dan engine, which would give her a speed of about eight miles an hour, or two engines of the same power to obtain a speed of 11 miles. The latter scheme, however, is not recommended, owing to the beam of the vessel being only 14ft., which would make the engine-room rather cramped. The vessel will be fitted with a solid propeller or propellers, driven through a powerful reverse gear, the limitation of the draught preventing the use of a reversible propeller. The heavy type of engine is well adapted for hard passenger work.

La Vague." A Fast Motor Yacht.

This vessel belongs to the full-powered motor yacht class, and combines good sea-going qualities with a very fair turn of speed. Her length is 54ft. and, fitted with a 30h.p. Gardner paraffin engine, she is capable of about 11 knots. For her size, accommodation, and speed, she is not an expensive boat, and there is, we are convinced, a great future for her and others of her type. She was built by Messrs. Turner Bros., Kingstown, and has, we believe, the distinction of being the largest motor yacht built in Ireland. The hull, with the greatest depth well forward and a very easy run, is a good type for speed, while there is plenty of beam for seaworthiness, enhanced by ample freeboard, especially forward. The sheer is pleasing, and combined with a fairly low cabin top, makes a very handsome boat.

In the fo'c'sle are two folding cots and lockers giving sufficient accommodation for a couple of hands. Aft, and divided from the forecastle by a bulkhead, is the engine-room, reached from the deck and giving ample room all round the motor. To economise space the after end of the room is recessed as shown to take the reverse gear, thus saving a good deal of space. At this point is a double bulkhead completely shutting off the crew's quarters and engine from the rest of the ship, and aft of it is a ladies' cabin containing two beds and ample locker accommodation, etc., and very well lit by ports and a skylight. Here and throughout the passengers' quarters there is ample headroom.

Aft of the ladies' cabin is a lavatory to port and a dresser to starboard, and aft of that again is the owner's cabin, containing a good-sized bed, a seat and wardrobe, dressing table and wash basin. There is also ample room for a chart table if desired. Next comes the dining saloon, 7ft. 9in. long and very comfortably fitted. A small companion leads to the little cockpit aft, which is of the self-draining type. There are skylights and ports to both the owner's cabin and the saloon. Finally the cabin top, being level, makes a very nice promenade deck. The steering wheel is fitted at the forward end of the cabin top

The whole boat has been designed for comfort rather than for maximum accommodation. For example, two berths might easily have been put in the owner's cabin, and by altering the arrangement of the saloon a couple more could have slept there. But the boat was built to individual requirements, and must be considered a very well-arranged and comfortable vessel. Mr. A. Sheppard is responsible for the design.

"Trident." A 64-ton Motor Yacht.

One of the largest full-powered motor yachts yet built in this country is "Trident," a boat that was completed towards the end of last summer, and which made a very favourable impression among yachtsmen.

She is 77ft. in length, 13ft. 10in beam, and 8ft. in depth, with a draught of 5ft. 4in., and, as her plans show, she is a powerful-looking vessel with plenty of freeboard.

With the exception of the deckhouse, there is practically no superstructure, so that the windage is less than usual in a boat of this type, and, moreover, she should roll very little. An auxiliary schooner rig is provided, the sail plan being roughly indicated below.

Very good deck space is provided, there being a forecastle deck forward with a hatchway leading below; then comes the deckhouse, with companion ladder leading to a ladies' cabin below. Aft of the deckhouse is the "bridge," or, rather, its equivalent, a steering platform; abaft this is the funnel, then the engine-room hatchway, and right aft a hatchway leading to the saloon and remaining cabins, etc. No cockpit is provided, as it is quite unnecessary in a boat of this size.

Below, the accommodation is very well arranged, though with a view to comfort rather than to cramming in the maximum number of passengers possible. In the forecastle, which is exceptionally roomy, and has 6ft. 9in. headroom, are four folding cots, while two doors in the forecastle bulkhead lead respectively to the galley and dresser and to the captain's cabin The latter is of ample size, and is fitted with a folding cot, wash basin, and chart table. Here the crew's quarters end, and are, it will be seen, completely isolated from the rest of the ship.

The deck saloon is entered from either the port or starboard, and contains an extremely comfortable lounge seat and table, with, as already stated, a companionway leading to the ladies' quarters, consisting of a very large double cabin with wardrobe, etc., all completely self-contained. Aft of the ladies' cabin, and double-bulkheaded off from the rest of the accommodation, is the engine room, of which more anon. To gain access to the rest of the ship it is necessary to descend through the hatchway right aft. At the bottom of the companionway is pantry and lavatory accommodation to port and starboard respectively. In the stern is a general store, and forward a double door leads into a good-sized saloon with two sofa berths, a folding table, and a fireplace

There are two doors in the forward saloon bulkhead, the one to port leading to a large state room, that to starboard giving access to the owner's cabin. For a 64-ton boat this is really surprisingly large, containing, besides a thoroughly comfortable berth, a lounge seat, writing table, and a drying cupboard cunningly arranged behind the saloon stove, where plenty of heat is available.

A great point about the cabins is the amount of headroom. The deck saloon, for instance, with its floor sunk below deck level, gives 6ft. 3in. clear, while there is 6ft. headroom in the ladies' cabin below, and 7ft. in all the remaining cabins.

The boat was built by Messrs. Woodnutt and Co., St. Helen's, I. of W., from the designs of Mr. A. Westmacott, M.I.N.A., who is responsible for the admirable cabin arrangements. Three Woodnutt paraffin engines are installed, $5\frac{1}{2}$in. bore by 6in. stroke, which develop 40h p. each at 700r.p.m., a very suitable speed for a cruiser of this type The total power is, therefore, 120h.p., and, with all three engines running, a speed of 11 knots is obtained. Six hundred gallons of fuel are carried in tanks at the forward end of the engine room, sufficient for a run of 610 nautical miles at full power, reckoning the consumption at .65 pint per h.p., which is about the figure that can be obtained with these engines.

With only two engines running, a speed of $9\frac{1}{4}$ knots is attained, and it will be possible to run at this speed for 780 miles, while, with only the centre engine in use, seven knots can be maintained for 1,240 miles The engine room is only 10ft. long, but, owing to the compactness of the motors, all are quite accessible, and, in addition, there is a small dynamo driven from the centre engine, and used for lighting the ship through accumulators All three motors exhaust into a special silencer in the funnel. The top part of the latter, it may be mentioned, lifts off to allow of passing under bridges, the masts being, of course, carried in tabernacles. A 13ft. dinghy and a 15ft. 8h.p. motor launch are carried in davits.

"Trident," it must not be forgotten, has *paraffin* engines, and will not therefore be very costly to run, in spite of her high power.

Harbour Service or Ship's Motor Launch.

This boat has been designed for use either as a ship's launch, or as a boat for general harbour service work, such as Custom's, police, or medical officer's launch. In addition to these uses, boats built from this design are now in use for pearl fishing in Ceylon, for towing and general purposes in Siberia, and for fishing in Natal. It will be seen that the boat has easy lines and good freeboard. She is strongly built of teak on American elm steamed timbers closely spaced, with heavy oak floors and massive engine beds There is also a stout transverse bulkhead under the thwart immediately aft of the engine. This, in conjunction with two heavy stringers running from end to end of the boat, and very heavy gunwales, enables her to stand any amount of knocking about.

The engine is a 7h.p. single-cylinder Dan, which drives her at a speed of over $7\frac{1}{2}$ miles an hour with a full load of passengers. Owing to the slow revolutions of the engine, and large diameter of the propeller, she is very suitable for towing purposes, while her light draught and small rise of floor enable her to be beached with safety. The total weight of boat and engine is under $1\frac{3}{4}$ tons, so that she could easily be carried in davits by a comparatively small vessel

The boat is shown with two transverse thwarts and side benches fore and aft, but if intended for carrying baggage or a small amount of cargo forward, the forward thwart and side benches would be removed. In addition to the bold sheer and high freeboard, there is a short whale-back deck forward, forming a roomy forepeak. Aft of this again is a spray hood of the Admiralty type to protect the forward part of the boat. The engine has a light steel engine casing which gives easy access to all parts, and the seating accommodation in the after part of the boat is fitted with an awning. The steering gear is arranged so that there is a wheel close to the engine in addition to the tiller aft; one man is therefore able to run the boat single-handed, an important point in a harbour service launch

Auxiliary Motor Trawler "Ibis III."

"Ibis III." was designed by Messrs. Linton Hope and Co. for H.R.H. Prince Albert of Belgium, who has presented her to the Belgian School of Fisheries at Ostend. She is somewhat of a departure from the ordinary type of sailing trawler, her lines being much finer, and the form altogether more up to date. She has now been at work for some time, and has proved herself a very able sea boat, with a good turn of speed. She is fitted with a 30h.p. two-cylinder Dan engine, driving a large motor capstan. Her mean speed under power alone is $5\frac{1}{4}$ knots. Considering her large displacement (114 tons) this is a very good result from such a small engine, and the owners are so well satisfied that two smaller vessels have been designed by the same firm. One peculiarity of "Ibis" is that, in addition to her ordinary fish hold, she has a cabin amidships for the fishery instructors, and a large forecastle forward with accommodation for 14 boys, who are taken to sea for instruction in modern deep-sea fishing.

It may be well to point out that "Ibis" is fitted with a ketch rig, with large sail area, and is, in fact, in all essentials a regular sailing trawler, the presence of the motor in no way interfering with her sailing qualities.

It is not claimed for auxiliary vessels of this type that they can compete with the larger steam trawlers now in use, but the addition of the motor greatly increases the earning power of the sailing trawler, while the total cost of the whole vessel new is only about one quarter of the steam trawler, the working expenses being infinitely less. This boat was designed by Messrs. Linton Hope and Co.

"Erica." A Fast Day Cruiser.

The boat now before us is a fast, fine-weather cruiser of German origin, and may be regarded as a connecting link between the launch and the cruiser. The type is not one that has come at all into favour in this country; indeed, we cannot recall more than one or two examples; but, for inland waterways or for coasts better sheltered than those of Great Britain, such boats as "Erica" are very largely used as day cruisers.

Her length is 12 metres (39ft. 4in.), beam 6ft. 9in., and extreme draught 3ft 1in. Her engine is a "Reversator," a special type of eight-cylinder four-crank tandem motor, and her speed is just under 15 knots, which, seeing that the displacement is $4\frac{1}{2}$ tons, must be considered a very good result.

The engine is installed rather far forward, and a galvanised superstructure makes a regular engine-room, taking the place of engine cover or spray hood. It is entered from aft and is quite distinct from the passenger accommodation. The exhaust is taken up through a funnel arranged also to take air from the engine-room on the ejector principle. A relief pipe from the crankcase is taken to the funnel in the same way, and there are two ventilating cowls, one for the engine-room and the other going direct to the crankcase. This system of ventilation appears to be extremely efficient, for the engine-room is kept perfectly cool and clear of fumes, and so, too, is the crankcase and lubricating oil, even on the longest runs.

The boat is steered from a point just aft of the engine-room, with which there is the usual telegraph communication. There is a roomy cockpit for passengers, the forward part of it being covered by a cabin top, very well lighted and large enough to enable meals to be taken in comfort, a point that will be appreciated by anyone who has had to eat in a fast open launch, when everything takes an unpleasantly wet, salt taste.

The "Reversator" motor, it must be remembered, is reversible, and, consequently, no reverse gear is fitted, only a clutch. The boat was built early this year in the Howaldtswerke yard, Kiel, and has taken a prominent part in Continental racing.

A Powerful Motor Tug.

For almost any sort of commercial work a heavy, slow-running engine is required, but there is, perhaps, no purpose for which it is so essential as for a tug. An excellent example of the possibilities of the internal-combustion engine in this direction is afforded by the vessel now under consideration. She is 42ft. long between perpendiculars, 46ft. 6in. o.a. by 11ft. beam and 5ft. 9in. deep, the draught being 4ft. 6in. The hull is built of mild steel with quarter-inch plating and frames 2in. by 2in. by $\frac{1}{2}$in. spaced 16in. The decks also are constructed of steel, sheathed with teak.

The engine is a two-cylinder Kromhout, developing 75b.h.p. at the extremely low speed of 265r.p.m. and driving a four-bladed cast-iron propeller 3ft. 8in. diameter. The speed attained (not, of course, when towing) is $9\frac{1}{4}$ knots. The boat is now doing work in the West Indies, having been sent out in plates and angles for re-erection at her destination.

Being for so hot a climate, an awning has been provided, but this, naturally, cannot be used while towing. Amidships is the engine-room, where one would expect the heat to be almost unbearable, though, as a matter of fact, it is not as great as would be supposed, owing to the combustion heads of the cylinders, where most of the heat is developed, being above the deck level and immediately under a large skylight.

Forward is a companion giving access to the engine-room and the forecastle, and aft is a comfortable cockpit. The wheel is amidships, and the big towing cleat will be noticed on the forward end of the cockpit.

Remembering how much of her time a steam tug is lying idle with steam up, it is easy to understand what a very great saving can be effected by the use of the internal-combustion engine, which does not use any fuel at all when not in actual service.

A Hydroplane.

Though invented as long ago as 1872, it is only during the last two years that hydroplanes have come into any prominence, but to-day they occupy a very prominent place indeed among those devotees of marine motoring who take most interest in racing. Briefly, a hydroplane is designed to lift on to the surface and skim along instead of cutting through the water like an ordinary boat, and as the resistance is enormously reduced thereby, very little power suffices for very high speed indeed. Hull and engine can be constructed very cheaply, and hence the phenomenally rapid access of popularity that the type enjoys among those to whom the fascination of speed appeals and who have but moderate means wherewith to gratify it.

Hydroplanes depend for lifting power on planes just as does an aeroplane. Once they have risen to the surface they skim along with practically no displacement at all.

Broadly speaking, there are two distinct classes of hydroplane. The two-plane type commonly known as the Ricochet class, evolved by M. Maurice Le Las in France, and the multiplane type, which may be either flat-bottomed or with hollow V sections, the latter being known as the Fauber. In the present state of knowledge, it is not possible to say which is the right system, but the Ricochet is by far the cheapest to build, and is at present the most popular, at any rate, in small sizes. We illustrate herewith a hull of the latter type designed specially for the M.Y.C. hydroplane class.

The length is 13ft. o.a. and about 11ft. 6in. l.w.l. by 4ft. beam. Practically the boat may be regarded as a punt with a "step" in it. The position of this step is one of the most important factors in hydroplane design, also one about which very little is known, except to one or two people, who very naturally keep their knowledge to themselves. It is, however, generally accepted that the step should be forward of amidships, and in the present case it is 6ft. from the bow and its depth 4in.

The angle of the planes is another matter open to question, though, broadly speaking, it may be reduced as the speed increases. In the design shown, the forward plane might perhaps have been made a little less steep with advantage if intended for an engine of extremely high power.

To comply with the club rules, the engine must be a two-cylinder one of 4in. bore or the international equivalent. The power developed by such a motor would vary with the design from 15 to 30h.p. With an engine of about 25h.p. and of a total weight of 650lb., including helmsman and fuel, the boat shown should attain a speed of 24 or 25 knots. It will be noticed that the engine bearers are carried nearly the whole length of the boat, which is essential on account of the very heavy longitudinal stresses set up by the pounding action of the planes, also that they come up to the deck level all through the after part of the boat. This construction gives an unnecessary degree of strength, but it has been adapted to comply with the requirement that there should be two watertight compartments, either of them capable of floating the boat. A compartment is obtained under each side deck from the step to the transom, and this construction therefore provides a very easy and cheap method of complying with the rule. A hull such as this could be built for £18 or so, whence it will be seen that expense is not a very serious item in a hydroplane.

MARINE MOTORS.

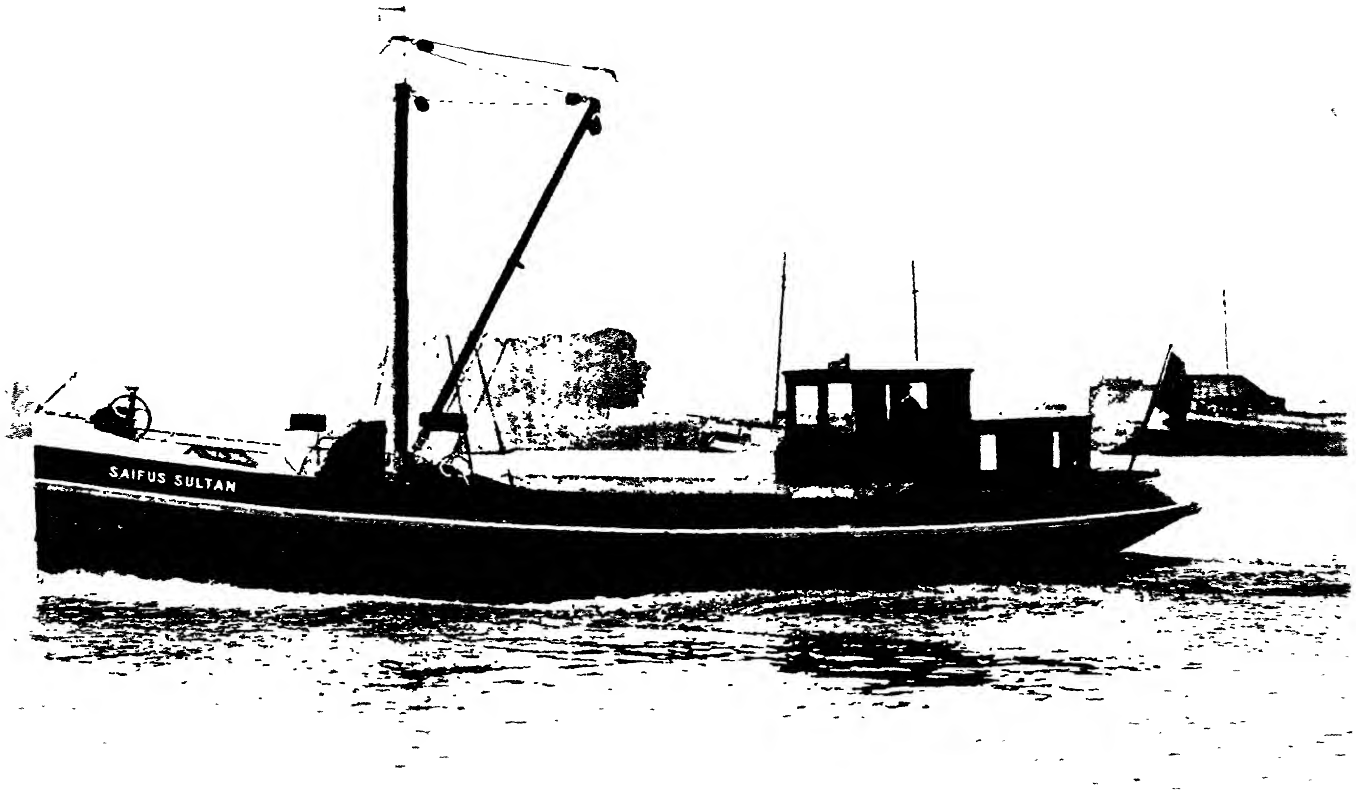
INTRODUCTORY.

In treating a subject of such wide scope and of such varied character as the propulsive mechanism of motor craft, classification must necessarily be arranged on a broad basis. So diverse are the types and so numerous the classes of boats and vessels in which they can suitably be installed that an encyclopædic classification would extend beyond two score headings. Yet, whilst such a system is to be recommended in a standard work of reference, it is too ponderous for the short review presented in the following pages. Far more serviceable, and responding better to the developments of the marine motor world at the present day, is the shorter and simpler division into seven categories, as follow :

For Private Craft.	Petrol	Four-stroke cycle	Single-cylinder engines, Class I.
			Multi-cylinder engines, Class II.
		Two-stroke cycle	Engines of all sizes, Class III.
	Paraffin, both cycles		High-speed engines, Class IV.
			Medium-speed engines, Class V.
For Commercial Craft.	Paraffin ...		Medium-speed engines, Class V.
			Slow-speed engines, Class VI.
	Suction gas ...		All sizes of plant and engines, Class VII.

In this manner the descriptions of the leading features of what we consider to be representative types of marine motors on the market have been in the following pages rationally grouped according to types, thus permitting those interested to discover, without trouble or inconvenience, all classes of engines that comply with their requirements. That the classes should in certain instances overlap has been unavoidable, and it has been impossible to adhere rigidly to any arbitrary limit of speed in those classes where speed determines the classification. In Class V. also a certain elasticity of limits has been compulsory, for it is difficult to determine the respective spheres of utility of these engines for pleasure and commercial applications. For the rest, there is only to be added that whilst a critical review of modern marine motors might interest a few, the greater number seek to learn the salient distinctions between current models, and it is for these latter that the section of this volume devoted to engines has been compiled. It is upon the proof of trustworthiness and reliability that the final choice depends : it is to aid in the selection of engines that are suitable for the particular requirements in view that this chapter of the book renders its service. When it is borne in mind that the interest of this " Manual " is universal, and extends beyond the United Kingdom to the Colonies and Dependencies of the British Empire, and, further, to lands that are under foreign dominion, it will be realised by the home readers why a number of engines have been included that are comparatively little known in this country, although of it. The locality of manufacture has a great importance overseas. For any deficiencies that may be found in the following pages, it is to be pleaded that detailed improvements and alterations in models are of constant occurrence, but inasmuch as the 1909 models have been as far as possible treated, the descriptions will in most cases remain serviceable for a long period.

One other point. A certain amount of knowledge on the part of the reader has been assumed. We have not attempted to deal with the elements of the subject, and we would refer the complete novice to " The Motor Manual," price 1s. 6d., which deals fully with first principles.



A motor tug 62ft. 6in. long, fitted with two 20h.p. Kromhout motors. She is in use in India, and besides towing work she can carry 20 to 30 tons of cargo.

Section 1.—Engines for Private Craft.

Class 1.

The following petrol four-cycle single-cylinder engines are dealt with :—

Ailsa Craig.	Gardner.
Barcar.	Halmax.
Blake.	Parsons.
Brooke.	Rogers.
Channel.	Scout.
Dixon-Hutchinson.	Thornycroft.
Fairbanks-Morse.	Wear.

The Ailsa Craig Motor.

Of the special features of the latest engine of this name the most prominent and the most important is the thorough protection afforded to all parts against damp and spray. A reference to Fig. 1 demonstrates very clearly the extent to which this wholesome attribute has been tended. The single-piece cylinder casting comprises a double valve pocket on the port side, with an open box underneath of the same width and depth and extending to the base of the casting. A detachable lid, fastened by a central bolt, serves to render the box tight, the valve stems, springs and tappets enclosed therein thus being protected from all predisposing causes of rust. The lid or panel is in the illustration shown beneath the starting handle. One casting serving to form the crankcase, the gearing is encased in a separate chamber bolted thereto. Of the accessory details that should be protected from damp there remain only the ignition parts, and of these, not only is the contact breaker encased—almost necessarily so—but the sparking plug is fitted with a hood that serves to guard the insulation from moisture, as well as providing a terminal for the high-tension wire. By these devices an engine casing is rendered superfluous, and there is the great merit of enclosed valve gear that the clatter of the tappets is deadened. Another feature of the Ailsa Craig engine is the offsetting of the cylinder. This means that the axis of the cylinder is set slightly in advance of the centre line of the crankshaft. When the maximum effort of the working stroke occurs, the connecting rod is, therefore, practically vertical and parallel with the sides of the cylinder, the consequence being that there is only a direct thrust on the piston, with no side thrust whatever on the cylinder walls. A mechanical advantage is also gained at the end of the compression stroke. A gain in power and smoothness of running is obtained. To secure the gudgeon pin two set screws are used, and through these a piece of wire is passed, the gudgeon pin being hollow; for additional security, one of the piston rings overlaps the ends of the pin. Flanged ball expansion joints are used on the water and exhaust pipes, the expansion joints effectually preventing leakage and the flanges facilitating removal and attachment. One of these joints may be seen in Fig. 1 fitted to the exhaust outlet and provided with a pipe through which water from the cylinder jackets is sprayed directly into the exhaust pipe, the flow being regulated by the cock above. The pump is coupled to its driving gear by a flexible spring,

Fig. 1.—3h.p. Ailsa Craig.

Fig. 2.—Blake 3h.p. motor.

and a slotted attachment permits its removal when desired by the mere slacking of two nuts. Forced-feed lubrication is fitted throughout. All the control levers are mounted rigidly on the engine. In addition to the timing and hand-operated throttle levers, there is a hand control for extra air and an enclosed governor working on the throttle. Inspection of the crank chamber is provided by the removal of a horizontal cover on a large wedge-shaped case on the opposite side to the valves and thus not visible in Fig. 1. A single winged nut fixes the panel. As a useful engine for hard work and exposure in all weathers the Ailsa Craig must be admitted to possess great advantages, responding, as it does in such a large measure, to the principal requirements of a marine motor. A single-cylinder engine of 6-8h.p., possessing the same characteristic features, but differing in some details, is also made by this firm.

An Accessible Motor.

We have now to consider the 3h.p. Barcar engine designed in such a manner that it can be installed under a casing in a dinghy without any diminution of accessibility to the chief accessory details. The automatic inlet valve is placed over the exhaust valve on the starboard side of the cylinder, which is mounted on a square crank-case, wherein all the gearing is enclosed, and on the port side of which is an inspection hole. Although the carburetter is placed low in order to work with a gravity feed, the throttle in the mixing chamber is regulated by a lever at the top of the induction pipe on a level with the cylinder head. At the same spot is fixed the lever that controls the ignition timing. In this position both levers may protrude from the engine casing through a slot. High-tension ignition by means of a coil and accumulator is fitted as a standard, and not only is the sparking plug in an accessible position at the top of the engine, but the wipe contact breaker is placed above the level of the cylinder head on a vertical shaft driven by bevel gearing off the camshaft. With the same idea of accessibility from above, a long vertical pipe is carried up from the base chamber to permit the supply of oil for the splash lubrication to be easily replenished. Both fly-wheel and chain-starting gear are fitted forward in order to give greater facilities for raking the propeller shaft. The water pump is attached to the end of an extension of the camshaft at the rear, and at such a distance from the crank-case that it can project beyond an engine casing, leaving the screw-down grease cups in a handy position where they act as a visible reminder of the attention they need. It is also a good feature of this model that the engine turns normally at only 800 revolutions per minute.

The Blake Engine.

A useful little engine of 3h.p. is included amongst the Blake models. Except for its automatic inlet valve and for the position of the exhaust valve, it possesses all the characteristics of the Blake motors described in Class II. The neatness of the 3h.p. pattern can be gathered from Fig. 2, which represents it denuded of piping.

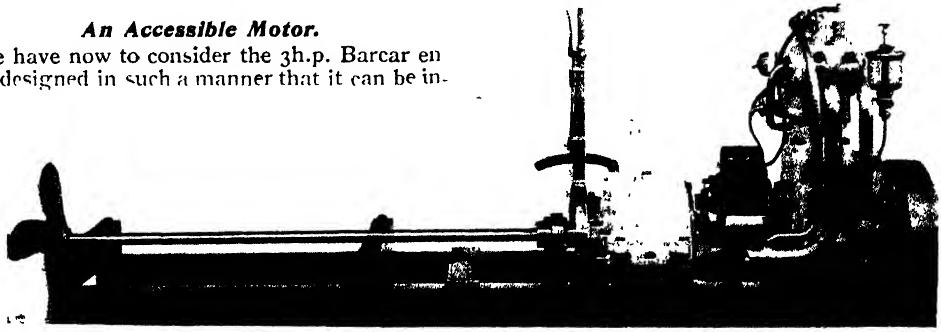


Fig. 3.—A 4h.p. Brooke marine set.

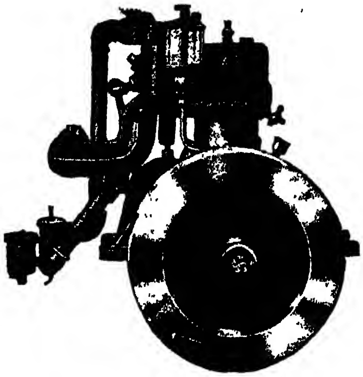


Fig. 4.—A small American motor.

An Example of Careful Design.

Amongst the few low-powered, single-cylinder engines that are constructed with the same regard for refinement as the more powerful multi-cylinder motors, not the least noteworthy is the Brooke 4h.p. model, illustrated in Fig. 3. The cylinder is cast with the valves side by side to starboard, the camshaft and its gearing being enclosed in a compact crankcase, designed to afford ample inspection facilities through its side doors, which are comparatively large for a small single-cylinder engine. An extension of the camshaft aft drives the high-tension magneto used for ignition, whilst a forward extension gives the drive for the water-circulating pump. The water is led into the jacket around the exhaust valve chamber, which also, being so close to the inlet valve chamber, is very efficiently cooled. After passing round the cylinder it is taken through a small pipe, following the curve of the exhaust pipe until the floor level is reached, where it is discharged into the exhaust. This method has the advantage that there is no difficult joint to be made, as there is when the exhaust pipe is jacketed right away from the valve chamber. An almost unique feature is the large size of the water drain cocks, which are too often of toyish dimensions and apt to choke. The float-feed carburetter is of a special pattern, designed to have a constant petrol level at all angles which the boat may assume. Another example of the robustness of the fittings is found in the trembler switch fixed at the after end of the cylinder. Splash lubrication, with a hand pump for replenishment, is employed in this model.

The 6h.p. Channel Motor.

In the single-cylinder 6h.p. Channel engine there is, of course, no scope for the salient features of the multi-cylinder design of the same type. Apart from the disposition of the cylinders, it is constructed on the same lines as those described in Class II., except that a rotary water-circulating pump is used instead of a semi-rotary.

The D. B. and H. Engine.

Motors of 5h.p. and 7h.p., with a single-cylinder and crankcase section, forming the essential units of the Dixon-Hutchinson system of construction, fully described in Class II., are made for small boats.

Fairbanks-Morse.

In this, one of the best types of engines made in the United States, there is the stamp of the most advanced American practice, marine motors on the other side of the Atlantic all exhibiting a greater contrast from automobile practice than on this side. A general idea of the construction can be gathered from Fig. 4, where it can be noticed that the cylinder is cast in one piece with its head and valve-pocket. From an ordinary float-feed carburetter the mixture is admitted through an automatic valve into the combustion chamber, the throttle being situated in a box over the valve. A short, flanged pipe leads the burnt gases to the water-cooled expansion box, into which the water flows from the cylinder jackets. A plunger pump, driven off an extension of the camshaft at the forward end, maintains the circulation. A large hand-hole is fitted to the crank chamber, in which lubrication is effected by splash, a drip-feed being fitted for the cylinder walls, and grease-cups to the main bearings in addition. High-tension ignition by accumulator and coil has been adopted, the contact breaker being mounted on the forward camshaft extension. Drain cocks are fitted both to the cylinder and exhaust jackets. Instead of the customary chain-starting gear or crankshaft handle, a large hand-piece, folding automatically into the flywheel, is used. This being mounted forward and the handle being in the rim, a very simple and convenient starting arrangement with a good leverage is obtained. This engine develops 4½h.p. at 800 revs per minute.

The Small Gardner Motor.

Although this name is more popularly associated with paraffin than with petrol, and perhaps to some solely associated therewith, no review of marine motors would be complete without a reference to the Gardner petrol engines. Two series of this type are made, and each includes a single-cylinder motor, the one developing 4¼h.p. at 1,000 revs. per minute, and the other giving 5h.p. at 600r.p.m., the former being intended for pleasure boats and the latter for heavier service. An excellent view of the 4¼h.p. model is given in Fig. 5, where the general disposition of the details can be plainly seen. A simple type of carburetter supplies the mixture to the cylinder through an automatic valve, the cover of which forms a chamber for the throttle that is controlled by the governor. Hot air is taken in through a sleeve round the exhaust pipe to form the mixture, for the alteration of which

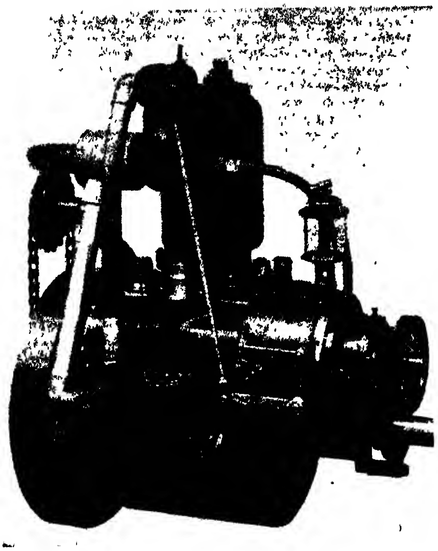


Fig. 5.—Gardner fast-running engine.

provision is made. The actual speed control rests with the adjustment of the governor whilst running. The camshaft gearing is enclosed, but the spur wheels driving the circulating pump are only covered. A strainer is provided on the suction pipe of the pump. High-tension electric ignition is fitted, the contact breaker, which is of solid construction, being mounted next to the governor on the camshaft extension. It is thus a simple engine, but having been designed specially for boat installations by a firm with long experience of marine oil engines, it makes a very sound job. The leading features of the heavier single-cylinder model will be found under the heading "Gardner" in Class II.

The Halmax.

A small motor of $2\frac{1}{2}$h.p. of the simplest construction is marketed under this name. Inasmuch as it is provided with inspection doors to the crankcase it is an exception amongst dinghy engines. A Longuemare carburetter is fitted, and, except that it has an automatic inlet valve, it is similar to the larger engine described in Class II. Castings of this, of a smaller $1\frac{1}{2}$h.p. model, and of several larger patterns, are supplied to amateurs who wish to build their own engines.

The Parsons Motor.

As evident from the description of the Parsons engines in Class IV., the single-cylinder 7h.p. model to which reference is there made can be run exclusively on petrol, the power developed being practically the same, because neither the compression nor engine-speed are altered.

A West of England Motor.

Being established in South Wales, as well as on the borders of Devon and Cornwall, the manufacturers of the Rogers engines make a special appeal to the clientele in the West of England. Both single-cylinder motors, of 5h.p. and 8h.p. respectively, possess the same characteristics. The valves are side by side, operated by tappets, which, being provided with balls at the lower end, work smoothly over the cams. All the gearing is enclosed, and the plunger water pump is worked by an eccentric on an extension of the camshaft, the contact breaker being fitted to a similar extension at the other end. A large door is fitted to the crankcase. Lubrication is by splash, and the main bearings are fitted with oil-tight rings. These engines are designed to turn only at 700 revs. per minute.

Scout.

An entirely new design has superseded that previously known in connection with Scout engines. Only one single-cylinder model is made, that being rated at 4h.p. Both valves, now mechanically operated, are situated side by side in an overhanging valve chamber, the top of the cylinder being, in the new design illustrated in Fig. 6, entirely clear except for the sparking plug, the valve caps and the water-outlet pipe. Ample water cooling has been arranged around the exhaust valve and the neck of the

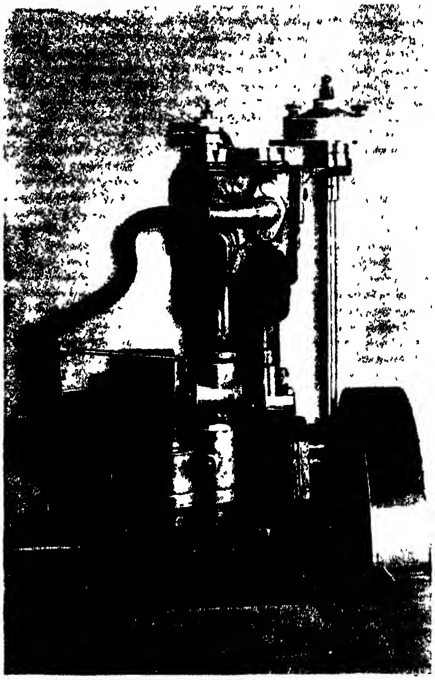


Fig. 6.—Scout 4h.p. engine.

exhaust pipe that protrudes from the valve chamber. This allows the exhaust gases to be taken away sufficiently cool directly to the silencer. The camshaft gearing is encased in a separate box at the forward end, but at the after end the skew gear on the camshaft extension is deemed sufficiently protected by the flywheel. This skew gear drives the vertical spindle on which the contact breaker is mounted at the level of the cylinder head. The water-circulating pump is driven by gearing off the camshaft at the forward end and forces the water into the cylinder jacket around the exhaust-cooling chamber, which thus obtains the coldest water. A simple type of carburetter of Scout design is employed, the throttle being controlled by the ball governor, which in turn is regulated by hand. Sight-feed lubrication with splash in the crank chamber has been adopted. A notable departure from previous Scout practice is the reduction of the height of the centre of gravity by the abolition of all the top gear.

Thornycroft.

A description applicable to the single-cylinder 9h.p. Thornycroft engine will be found under this heading in Class II. When the engine speed is reduced to 750 revolutions per minute $7\frac{1}{2}$h.p. is developed. No smaller engine is made by the firm.

Wear.

Engines of $2\frac{3}{4}$h.p., 4h.p. and 9h.p. are constructed by the Wear firm, all turning at a moderate speed. A description of their leading features will be found in the next class.

Class II.

The following petrol four-cycle multi-cylinder engines are dealt with:—

Ailsa Craig.
Barcar.
Blake.
Brit.
Brooke.
Buffalo.
Channel.
Dixon-Hutchinson.
Fairbanks-Morse.
Gardner.
Halmax.
Kelvin.
King-Lamb.
Knight-Silent (Daimler)
Maudslay.
Napier.
Parsons.
Rogers.
Scout.
Simms.
Standard.
Thornycroft.
Wear.

Ailsa Craig Engines.

A double-cylinder motor of 6-8h.p., conceived on exactly the same lines as the single-cylinder described in Class I., with which it is identical except for the duplication of the cylinders, forms the smallest of the multi-cylinder Ailsa Craig series. Two, four and six-cylinder units of 12h.p., 24h.p. and 36h.p. respectively complete the range of models. Except that they are fitted with compression cocks and that the contact breaker is mounted in a handy position on a vertical spindle, they differ only from the model described in Class I. by the details involved in the multiplication of the cylinders.

Barcar Models.

In addition to a 6h.p. double-cylinder model, possessing the same distinctive features as the 3h.p. engine described in Class I., and from which it differs only by the addition of an oil pump drawing directly from a sump in the crankcase and delivering a jet directly on the big ends of the connecting rods, there are also 12h.p. and 24h.p. Barcar models, with two and four cylinders respectively. These are of a slightly different pattern from the two smaller types. They are controlled by a throttle attached to a centrifugal governor, which can be adjusted to any speed whilst the engine is running. Mechanical inlet valves are employed, fitted on the opposite side to the exhaust valves, through which the burnt gases are discharged directly into a water-cooled expansion box. The control levers are not permanently fixed to the top of the engine as in the smaller models, because, with the more expensive installation, they should preferably be mounted on a control board. Magneto ignition is supplied as a standard with the four-cylinder engine, which has thus dual ignition with one set of plugs. In other details neither of the bigger models differ from the smaller ones.

A Well-established Motor.

One of the earliest and best-famed of marine motors is the Blake, for it has now been on the market for more than ten years and has proved itself a thoroughly trustworthy engine. It is a smart, clean piece of work, as Fig. 7, which illustrates a four-cylinder 40h.p., testifies. In Blake practice the crankcase is cast in one piece open-ended, the end main bearings being

carried in the faced end plates. With this method the wide inspection panels to the crank-case are a prime necessity for taking up any slack bearing. The camshafts are carried in a peculiar manner, cam pockets in pairs forming an integral portion of the base chamber. Herein the cams run in an oil bath, whilst, however, being far more accessible than when entirely enclosed inside the crank chamber. It matters little that portions of the camshaft are exposed, for it is only the lay sections that are thus treated. On both sides are the camshafts so disposed, the symmetrical half-timing gearing, which is driven off the forward end of the crank-shaft, being enclosed in a separate oil-tight casing. The cylinders are cast in pairs with their heads and valve pockets, but the large core panels on top of the water jackets give that access which should always be provided for cleaning out mud, etc. The valve caps are ground to their seatings and held down in pairs by yokes on the inlet side and fastened each by gates on the exhaust side. It is on the latter, or starboard, side that the relief compression cocks are fitted. For greater convenience these are connected to a single rod, but in such a manner that any particular one can be readily opened independently of the others. A water-cooled expansion box is attached directly to the exhaust outlets of the cylinders, and all the cooling water passes away round this. The automatic carburetter is arranged just under the exhaust box, with its air intake designed to collect hot air. The mixture passes through a pipe between the two pairs of cylinders to the evenly-branched passages leading to the inlet-valve chambers. Adjustable bearings are fitted between all the crank throws, and a neat method of taking up slack in the big-end bearings is also provided, in order that, once installed, the engine need not be taken off her engine bearers for several years. A combination of forced and splash lubrication is employed. As a standard it is high-tension ignition by accumulator and coil that is adopted. Four-cylinder Blake motors are rated at 12h.p., 18h.p., 25h.p. and 40h.p., whilst two-cylinder engines of 6h.p. and 9h.p. also belong to this class.

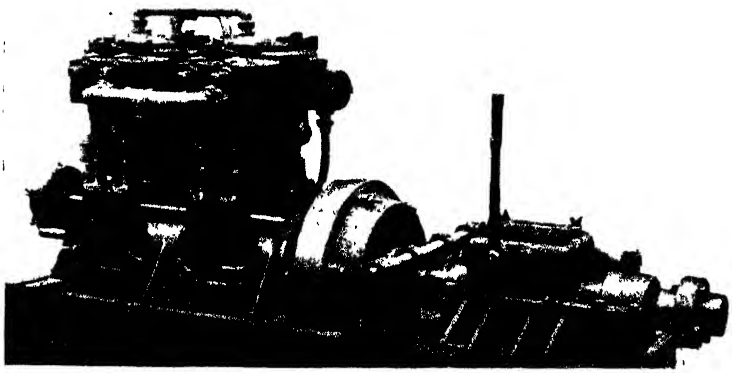


Fig. 7.—The 40h.p. Blake motor.

A Low-speed Motor.

The Brit 30h.p. four-cylinder engine is one of comparatively few that answer the purpose when a low-speed motor is required. Running only at 650 revolutions per minute, this is the type of petrol engine that is demanded for installation as auxiliary power in full-bodied vessels. As may be judged from Fig. 8, the construction makes a clean piece of work. All the valves are operated from one camshaft on the port side, the half-time gearing being enclosed in a box at the forward end, an extension through which serves to carry the contact breaker of the high-tension accumulator ignition. An extension of the camshaft at the after end carries a pinion to drive a lay pinion, to the face of which is fitted the plunger of the oil pump. From this pump, which draws its supply from a well in the base of the crank chamber, the oil is forced to a gallery of seven sight-feed glasses, five of which feed the main bearings, the remaining two each being branched to lubricate two crank pins. An evenly-forked induction system supplies each pair of cylinders, the throttle being under the control of the governor and of a hand lever. From the cylinder jackets, to which it is forced by a positive rotary pump driven directly off the forward end of the crankshaft, the water is conducted into the jacket that surrounds the exhaust-expansion box. Large access doors are fitted to the starboard side of the crankcase, and, in general, accessibility has been well studied. It is at once a stoutly-built, serviceable and well-designed engine, standing almost in a class by itself on account of its moderate speed. Cylinders of the same size as those used for the 30h.p. engine are also employed to form the two-cylinder 15h.p., and in the same manner the four-cylinder motors of 12h.p. and 16h.p. register with two-cylinder units of 6h.p. and 8h.p. respectively.

Brooke Engines.

Two, three, four and six-cylinder engines are included in the Brooke models, seven different sizes being made, counting the single-cylinder type. In design these vary to some extent, but

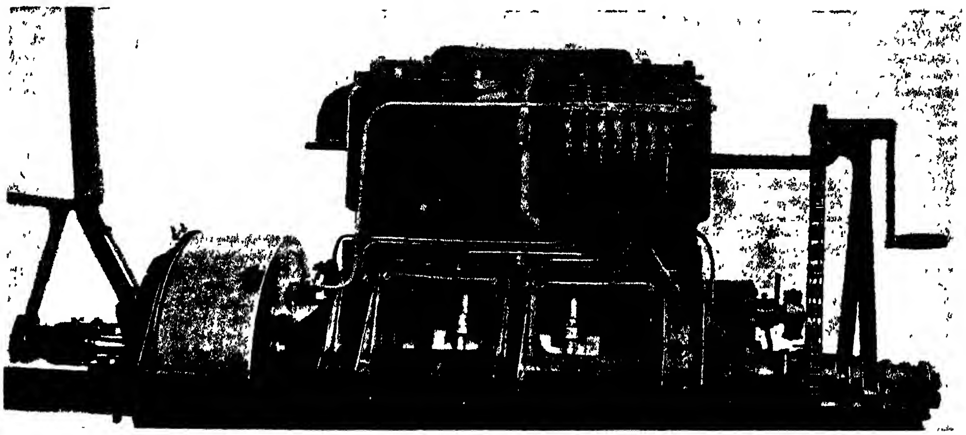


Fig. 8.—A moderate-speed engine of 38h.p.

chiefly in the cylinder construction. Thus the three cylinders of the 12h.p. motor are cast in one block with the valves all on one side; in the four-cylinder 18h.p. engine (Fig. 9) the cylinders are in pairs, but in the 45h.p. model are separate, the valves in both cases being on opposite sides; whilst in the six-cylinder 40h.p. engine (Fig. 10), as installed in the racing boats "Arab" and "Fleurette II," the cylinders are in pairs with the valves side by side. Except in the latter type, the gearing is all enclosed. All have high-tension magneto ignition and automatic carburetters with extra air-inlet valves. When a governor is fitted it acts on the throttle, which, however, is always subject to regulation by hand. Rotary water pumps are fitted. Lubrication is by splash in the crank chamber, which is sectioned to prevent the oil collecting aft on the engines just named, though we understand that a force-feed system is fitted to 1909 models. Grease cups are provided for the extension bearings of the governor and water pump. With reference to the three-cylinder models, it is to be observed that, the cranks being set at 120 degrees, there is an even sequence in the impulses and there is a balance between the moving parts. Although public favour has not been largely shown towards three-cylinder engines, this must be attributed to prejudice, for the type has no inherent disadvantages, and, on the contrary, it forms the most compact balanced engine that can be obtained.

A Well-known American Motor.

When first known in this country the Buffalo engine was imported from the United States, but it is now being manufactured on the Thames. It is built up on a framework similar to that of small, high-speed marine steam engines,

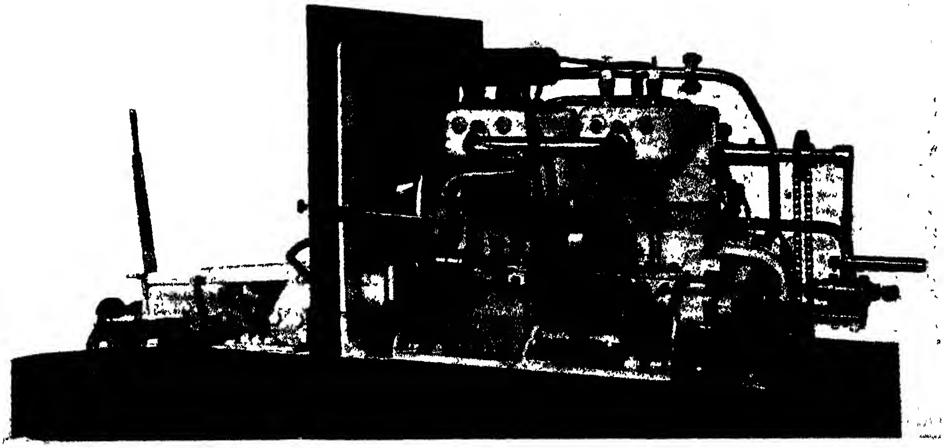


Fig. 9.—Brooke 18h.p. four-cylinder engine and gear.

with turned columns taking the stresses between the cylinders and the bed. This enables the crankcase to be made of much lighter construction with full-size inspection doors. Through these doors the pistons, with their connecting rods, can be removed, or they can be adjusted without disturbing other parts of the motor. Tappets and cams for the mechanically-operated valves can also be reached through these doors. A plunger pump is fitted for the water circulation, and large doors are fitted to the cylinder jackets to enable them to be cleaned out, a very useful feature, especially in tidal rivers, where mud is always suspended in the water, or where strong currents stir the sand. Bosch electromagnetic plugs, operated by a Bosch low-tension magneto, have now been adopted for the ignition. This system is bound to find more adherents in marine-motor practice, and already its advantages have been realised by a considerable number of designers. Forced lubrication has been fitted, but provision is made for lubrication by sight-feed and splash should the oil pump fail. The models range from 5h.p. upwards, the two-cylinder series developing 5h.p., 10h.p. and 15h.p. respectively, whilst the four-cylinder patterns give 20h p., 30h.p., 40h.p., 50h.p. and 75h.p. Larger engines of 130h p., 160h.p. and 200h.p. are also on the boards. All are rated by the M M.A. formula, the smallest at 1,200 revolutions per minute, the four next up to 30h.p. at 950 revolutions per minute, the 40h.p. at 700 revolutions per minute, the 50h.p. at 600 revolutions per minute, and the 75h.p. at 450 revolutions per minute.

A "V" Engine.

Channel motors are distinguished by inclined cylinders, set at right-angles to each other, but slightly out of line in order that the connecting rods of each pair may drive on the same crank pin. Two models are made: a four-cylinder 24h.p. and a two-cylinder 12h.p., the larger of which is represented in Fig. 11. The carburetter is mounted between the cylinders at the after end and delivers its mixture through automatic inlet valves. Only short exhaust pipes are required, the usual method being to discharge the burnt gases directly into a funnel silencer mounted between the cylinders. Only a single camshaft is required, and it can very easily be removed if necessary. The gearing, however, is not enclosed. A semi-rotary pump is employed for the water circulation, the pump being situated in a handy position on the starboard side and operated by an eccentric rod off the camshaft. Full-length inspection panels are fitted to the crankcase. Lubrication is served by splash. A great saving in weight and a reduction of vibration are claimed for this construction. As to the former, although the engine turns only at 750 revolutions per minute, the weight of the 24h.p. model is only 475lb., to which has to be added only very short piping. Much less space is also occupied, this amounting to 50 per cent. in the length, with but a slight increase in width. No internal bearings are used in either model.

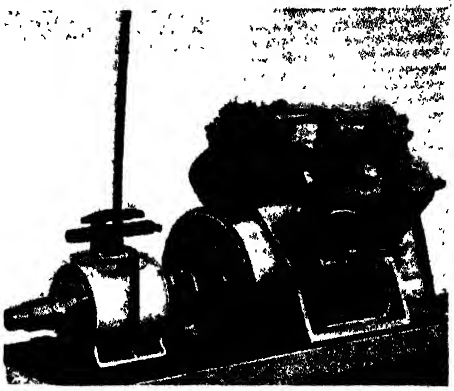


Fig. 11.—A Channel 24h.p. four-cylinder "V" engine and reverse gear. Weight of engine 475lb.

A Multiple Unit Series.

The well-ordered system of units which provides a progressive range of models, increasing in power according to the number of cylinders, but all subject to the same standardised measurement of parts, renders a description of any particular Dixon-Hutchinson engine applicable in detail to all

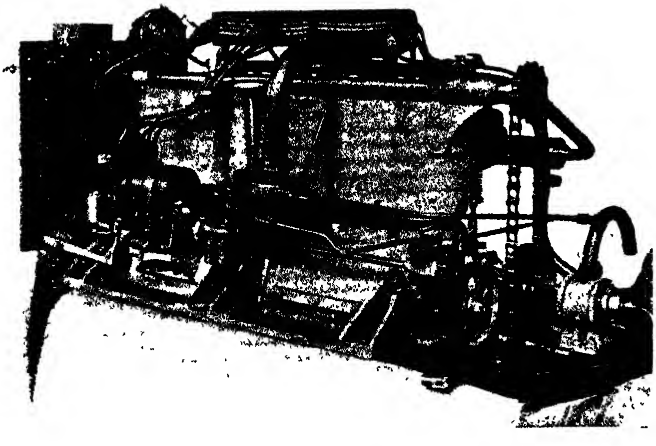


Fig. 10.-Brooke 45h.p. six-cylinder light motor, 4¼in. bore by 4¾in. stroke.

others. Each cylinder is rated to give 7h.p. at 950 revs. per minute, the four-cylinder motor represented in Fig. 12 being thus referred to as of 28h.p. A single casting embraces the cylinder, combustion head, and diametrically opposed inlet and exhaust valve chambers. According to the number of these figuring in the engine, so will there be sections in the base-chamber, each section being in one open-ended piece, rectangular above the shaft centre and circular below, but not split horizontally. Across the lower end of each section is a web for the support of a main bearing. In order to build up a complete crank chamber the cheeks of the sections are machined, then fitted together by a little countersinking and bolted up round the internal flanges, whereafter the webs are bored for the camshaft bearings and their a deep dish is formed in the end plate to take the half-time gearing, and a cover is fitted thereto, the wheels being thus completely enclosed in an oil-tight case. On the inlet side, a skew gear meshing with the camshaft wheel drives the vertical spindle on which the contact breaker is mounted. If a magneto be fitted to duplicate the ignition, it is fitted on a bracket at the forward end of the motor, and driven by gearing off the contact-breaker spindle, the whole forming a particularly compact and neat arrangement. Compression relief cocks are provided. The control, both of the throttle and ignition, is brought back to the after end of the engine and conveniently mounted on a transverse bar. Splash lubrication is relied upon, and in such an engine, where the crankshaft is provided with one bearing more than there are cylinders, and

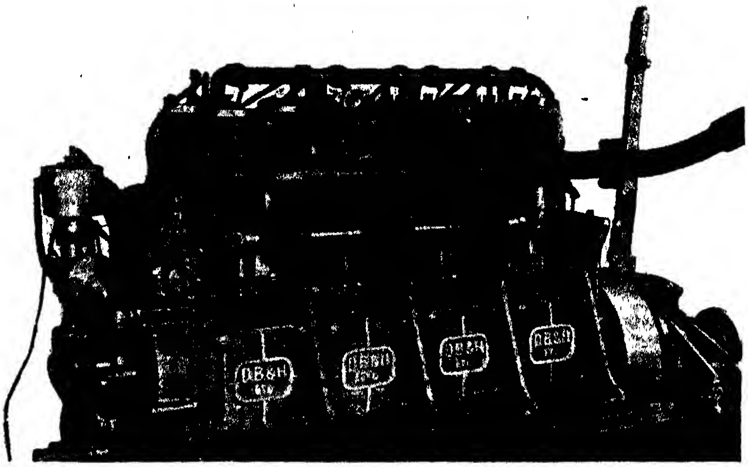


Fig. 12.—28h.p. D. B. and H. motor.

thickened bottom portions turned up for the plummer blocks of the main bearings, the top outer face planed, and with the end plates in position a complete entity is obtained. Big inspection doors are provided on each side of the crankcase sections. Each plummer block being held by only one bolt through the web, it is thus perfectly simple to remove the crankshaft in any case when it might be desired to do so. Even more easy is the withdrawal of the camshafts, for these, cut from a solid bar as in the best practice, have not projecting cams, as usually is the case in motor work, but sunk cams, the metal being cut away only at the cam positions, leaving the remainder of the shaft very large in diameter. Rollers are fitted to the lower ends of the steel tappets, which work in steel guides, a method that is now being adopted for the most refined racing engines, but little used in ordinary practice. At the forward end of the crankcase long bearings too, even the most captious could find no cause for criticism. In addition to the range provided by one, two, three, four, or six cylinders of 7h.p. per cylinder, a smaller series of 5h.p., 10h.p., 15h.p., and 20h.p. is obtained by the use of a smaller cylinder that fits the same crankcase sections. Standardisation could hardly be carried to a finer pitch.

The Fairbanks-Morse Engines.

A two-cylinder 9h.p. and a four-cylinder 18h.p. are obtained by the multiplication of the 4½h.p. cylinder described under this heading in Class I. All the chief points of the design are identical, but the induction piping is branched with one pipe to each pair of inlet valves, and the single throttle is placed low down instead of over the engine, the controlling lever being mounted on the after end of the crankcase next the ignition

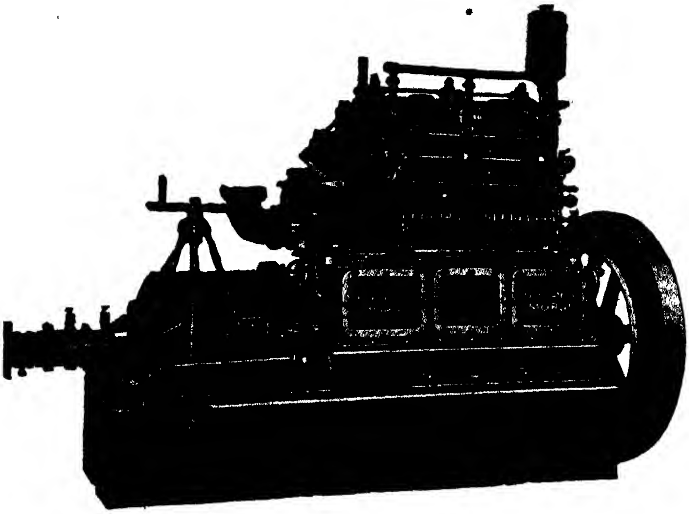


Fig. 13.—A heavy type of 75h.p.

engines must be particularly useful for heavy work, owing to their slow speed. The two-cylinder 10h.p. and three-cylinder 15h.p. turn at 400 revs. per minute; the two-cylinder 20h.p., three-cylinder 30h.p. and four-cylinder 40h.p. at 350 revs. per minute; and the two-cylinder 50h.p., three-cylinder 75h.p., and four-cylinder 100h.p. at 300 revs. per minute only. A three-cylinder 75h.p. model is illustrated in Fig. 13.

lever. A more thorough system of lubrication is also fitted. Inside the crankcase is a reservoir, from which the oil is drawn through a strainer by a pump and circulated to all the bearings. As it drips into the base it is carried up again to the reservoir and used afresh. One of the crankcase doors gives ready access to the reservoir for replenishment when necessary. Like the smaller model, the multi-cylinder engines are designed to run at 800 revs. per minute. In addition there is a series of slow-running motors, much used for commercial work in the States where the petrol spirit is comparatively cheap. In this type the cylinders are cast separately with all the valves on one side. Each inlet is provided with its own spray box, giving the mixture right into the combustion chamber, the control being effected by varying the feed, both governor and hand regulation being provided for this. An elaborate system of drip-feed lubrication to the various bearings is supplied from a large tank above the engine. Low-tension ignition is employed. In countries where spirit can be obtained at a reasonable price these

Two Gardner Types.

Two series of multi-cylinder petrol engines are listed under this name, the first comprising sets built up with cylinders of the general design described under the name "Gardner" in Class I., and the second being a range of slow-running engines developing 5h.p. per cylinder. Thus, although the four-cylinder models of both types are of very nearly equal power, giving 17h.p. and 20h.p. respectively, they virtually represent a greater difference by reason of the contrast in the engine speeds. As evidenced by Fig. 14, the cylinders are cast separately with the valves on opposite sides, with all camshaft gearing enclosed in the crank chamber, which is amply provisioned with inspection doors of a distinctive pattern which lends itself to the fitting of oil-fillers for each crankcase section. The mixture is conducted from a simple carburetter at the forward end through a dead-ended induction pipe lying along the inlet valve

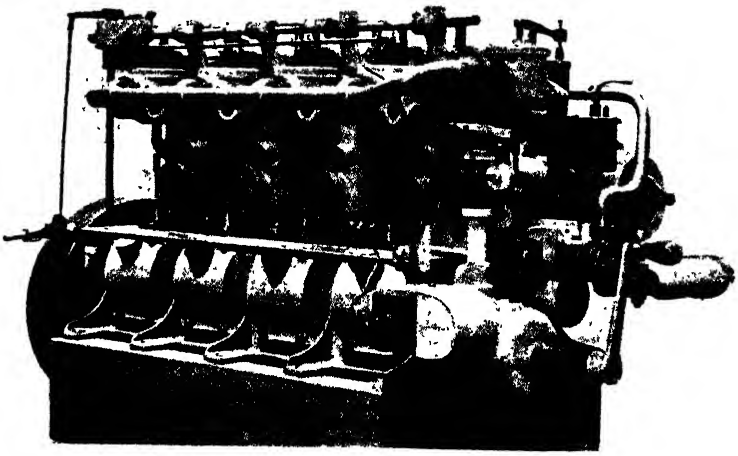


Fig. 14.—The Gardner heavy pattern petrol engine.

chambers. Just above the governor, which is on a vertical spindle driven by a camshaft extension, the induction pipe is fitted with a throttle chamber. As the governor weights fly out, this throttle tends to close, and by a simple expedient, clearly shown in the illustration, also varies the mixture. This arrangement of governor and carburetter saves a number of rods. Low-tension magneto ignition is fitted as a standard, and the timing is regulated by the governor, subject to the hand control. Except for the provision of a thoroughly effective water-cooled exhaust box fitted close up to the cylinders, there is nothing else about the design that needs comment, the details conforming to ordinary practice. As a robust, petrol engine suitable for heavy work where paraffin is taboo, this type stands almost in a class by itself, having been specially designed for such work, as in auxiliaries, for instance. Its comparatively low speed is a great asset in a number of cases.

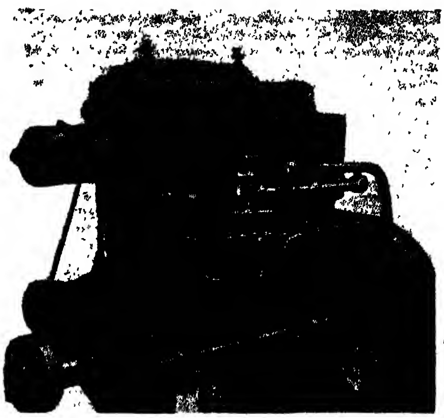


Fig. 15.—A 10h.p. four-cylinder engine.

A Simple Engine.

Although best known north of the Tweed, the Halmax models present a special interest by reason of the fact that the makers supply the castings to amateurs desirous of building their own engines. Because of this, the designs embody only the simplest needs of a motor. These engines are therefore very cheap, and thus supply the wants of many. The four-cylinder 10h.p. motor shown in Fig. 15 is typical of the Halmax pattern. Separate cylinders, with the valves all on one side, outside camshaft and gearing, cast-iron crankcase, drain and relief cocks, and sight-feed lubrication with splash in base chamber are the main features, and it will be recognised that they offer to the amateur the simplest possible construction. A two-cylinder outfit is also made.

A Clyde-built Engine.

On the Clyde especially considerable renown has been won by the Kelvin motors, which are Glasgow productions. For launch work two standard models are made: a two-cylinder 7-9h.p. and a four-cylinder 14-16h.p., the lower figure being the rating by M.M.A. formula at 850 revs. per minute. Cylinders are cast in pairs, with all valves on one side, and the low-tension ignition gear on top. A compact form of crankcase is employed, with a large inspection door to each pair of crankthrows and a smaller handhole, fastened by a thumb-screw, fitted to each door for more convenience. The fibre gearing used for driving the camshaft is not enclosed, being situated between the rear end of the crankcase and the flywheel. Splash lubrication has been adopted, but owing to the equalising arrangement in the crank chamber an inclination of 1 in 7 does not disturb the equal lubrication to each cylinder and its moving parts. There is no special feature in the automatic carburetter, but a petrol filter forms a standard attachment of the float chamber. For the water circulation the plunger type of pump is used, one being fitted to the smaller engine

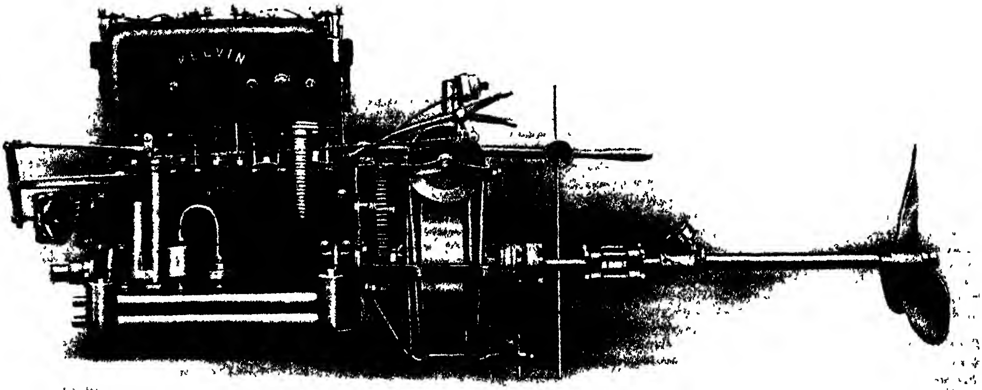


Fig. 16.—A compact marine set, including belt reverse gear.

and two on the four-cylinder model. After passing round the cylinder jackets the water is discharged into the cooling jacket of the exhaust expansion box fitted directly to the valve pockets and passes away round the exhaust pipe. This is a standard fitting sent out on every engine. A governor on the forward end of the crankshaft controls the throttle, but is also under the regulation of a hand lever mounted together with the ignition lever and magneto earthing switch above the flywheel, which is now completely protected from bilge water by a metal pan, not shown in the accompanying illustration of the four-cylinder model (Fig. 16). Whenever the clutch is taken out the engine throttles down to a quiet speed instead of running light and racing alternately. Two models have lately been added to the firm's list for auxiliary work. Both are heavily built, but except for their lower engine speed and power they contain the same features as the smaller types. The two-cylinder is rated at 15h.p. and the four-cylinder at 30h.p. An ingenious device attached to the low-tension magneto is said to enable the engine to be started without any cranking up, but this of course is subject to reasonable limitations of temperature and of mixture in the cylinders.

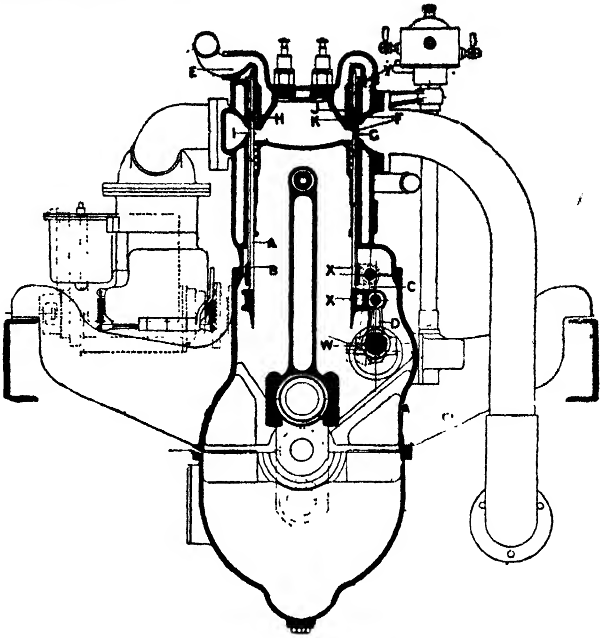


Fig. 17.—Section of new Daimler engine.

A Low-speed Motor.

Latest models of these engines show a very striking departure from all previous King-Lamb designs in the adoption of the almost universal casting of cylinder and jacket in one piece, instead of having the brass jacket pressed over the iron cylinder as heretofore favoured by the manufacturers. The separate cylinder head integral with the valve chambers is retained, all valves being on one side, and the water jackets of cylinder and head being connected by an exterior pipe. The water, after cooling the cylinder system, is discharged through the jacket of the exhaust expansion chamber, which is fitted right up to the cylinders. All gearing is enclosed, ample access is given to the crank chamber through a full-length panel, and accessibility has been fully studied, the approved modern practice as to the location of the contact breaker on a vertical spindle, inter-connection of hand and governor regulation of the throttle being adopted. The most interesting and novel feature is the lubrication. Oil from a tank situated at the upper end of the cylinder flows by gravity to each main bearing, whence it runs through the hollow crankshaft to the connecting-rod big-ends. Leaving these through proper openings, it is thrown up inside the piston and on the cylinder walls. The drippings fall into the crankcase, drain to the after end, and the oil is then pumped back to the gravity tank. These engines are made in two, three, four, and six-cylinder units from 12h.p. to 60h.p., the power being developed at only 450 revs. per minute. This engine, it will be gathered, belongs to the more robust type of petrol motor.

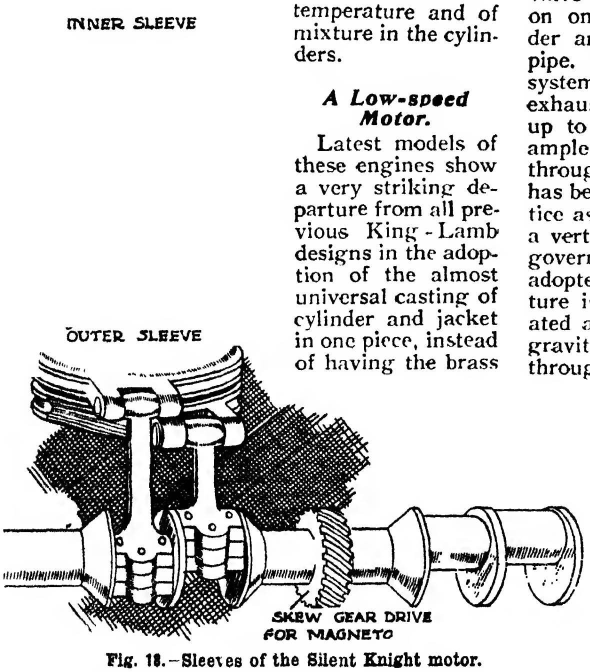


Fig. 18.—Sleeves of the Silent Knight motor.

The Knight (Silent) Engine.

Considerable stir has recently been created in the motor world by the introduction of the Knight Silent engine, wherein the usual mushroom or poppet valves have been replaced by sliding sleeve valves, with, it is claimed, a considerable gain in silence, controllability, efficiency, and liveliness. That the Daimler Co. in the United Kingdom, the Panhard firm in France, the Mercédès factory in Germany, and the Minerva works in Belgium should all have decided to adopt the Knight system will to most people prove sufficient guarantee that the engine must be a sound one, no matter what critics say, for such leading firms would not stake their reputation on a bubble. Let it be premised that the engine works on the Otto or four-stroke cycle, and has nothing in common with two-stroke motors. The simplest description of the construction is given by the statement that the mixture and exhaust gases respectively enter and leave the cylinder through wide ports in the cylinder wall that are uncovered during the correct periods by two sleeves interposed between the piston and cylinder walls. A first glance at Fig. 17 scarcely reveals the sleeves surrounding the piston, but it is at once evident that the ordinary mushroom valves are absent from the inlet passage (I) and from the exhaust passage (G). In the sleeves (A and B) there is a slot on each side, and it is by causing the slots on one side to register with the port in the cylinder wall that the gas passage is opened on that side. In Fig. 18 the sleeves are shown removed from the cylinder, and the eccentrics by which they are operated from a lay shaft, corresponding to the camshaft of the older type, are clearly seen. The piston, with its ordinary rings, travels up and down inside the inner sleeve, and the cylinder fits closely over the outer sleeve, in which one of the ports is apparent in the diagram. It is then simply by arranging the eccentrics in such a manner that the slots on the inlet side shall both register with the cylinder inlet port during the suction stroke, and those on the exhaust side with the cylinder exhaust port during the exhaust stroke, that the four operations of the Otto cycle are provided. During the compression and working strokes both inlet and exhaust ports are covered by the sleeves. The layshaft, by which the sleeves are actuated, is driven at half the crankshaft speed just as an ordinary camshaft, and in so far as the work which they perform is concerned the eccentrics may be regarded as cams and the eccentric rods as tappets. As can be gleaned from Fig. 17, the head is a separate piece, making a faced joint (Y) with the cylinder. This joint is not subject to the explosion pressure as in most designs where detachable heads are used, and need only be tight enough to prevent water-leakage from the jacket. It is relieved from the explosion pressure because it is provided with a coned annular flange (I, K), properly water-cooled, and provided with three ordinary piston rings, in addition to a wider ring, which is covered by a "junk" ring split into equal halves and prevented from rotating by pins. The top of the inner sleeve is always sliding on these rings, and the combustion chamber is therefore rendered tight at the top by the inner sleeve and at the bottom by the piston. No leakage can occur past the inner sleeve, for there is always a thin film of lubricating oil to seal the joint between the sleeve and the rings. Further reference to Fig. 17 will show the inner inlet ports (H) of both inner and outer sleeves, the exhaust ports (F) of both sleeves, the eccentric rods (C and D) for the outer and inner sleeves respectively, and W the actuating layshaft, XX being the collars by means of which the eccentric rods move the sleeves. It would require too much space to describe in detail and illustrate the positions of the sleeves at different periods during the cycle, but the main idea of their action can be sufficiently understood without such particulars. To fully enter into a consideration of the advantages mentioned in the opening lines of this description would also occupy too much space, but there seems no doubt that they can be amply substantiated. A novel departure in motor design is the silent chain drive between crankshaft and layshaft. Lubrication in the Daimler models of the Knight engine is by splash, holes being cut in both sleeves and a long, spiral groove in the inner sleeve to keep their surfaces oiled. That this method must be quite satisfactory can be gathered from

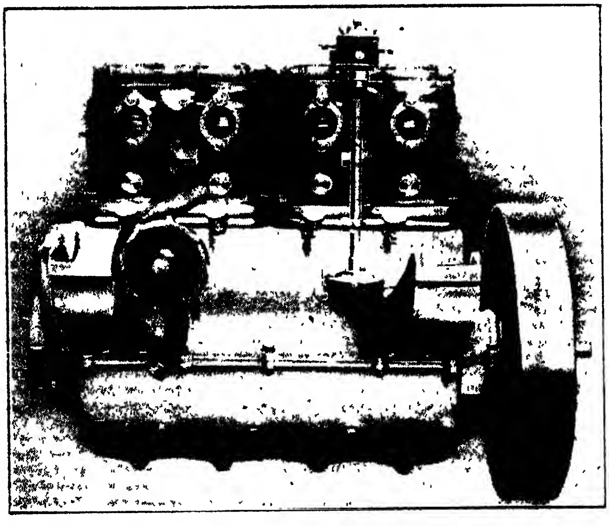


Fig. 19.—The new Daimler motor.

the fact that, in their 1908 models, the Daimler Co. employed forced lubrication. Dual ignition is the standard, there being two entirely independent systems, each with its own set of plugs, all of which are in the centre of the cylinder head. The magneto is driven by a transverse shaft, skew-geared to the layshaft between the forward pair of cylinders, and on the other end of which is placed the water-circulating pump (see Fig. 19). A second transverse shaft between the after pair of cylinders on the port side drives the vertical spindle on which the contact breaker for the coil and accumulator ignition is mounted. That the engine forms a good marine type with no exposed parts can be seen from Fig. 19, which represents the four-cylinder 38h.p. model, which, together with the 22h.p. and 48h.p. models, form the Daimler series. These figures are merely nominal, the power developed at 1,000 revolutions per minute being 30 per cent. greater, and at 1,500 revolutions per minute about 90 per cent. greater. The Minerva Co. will for the present only make a 38h.p. model, and the plans of the Panhard and Mercédès firms have not yet been disclosed.

An Accessible Engine.

As an example of the extent to which accessibility can be embodied in marine motor design no engine can serve better than the Maudslay. No method of construction could possibly give more ready and convenient access to the valves than is represented in Fig. 20, which shows a four-cylinder 30h.p. engine with the valve cages exposed. The camshaft, which lies along the top of the cylinders, is carried in a box borne on bridges that are hinged on the starboard side and bolted down on the port side. Inside the box the camshaft runs in oil, and the cams act on tappets that, protruding through the bottom of the case, operate the valves. When it is desired to get at the valves, the bolts on the port side are removed, and without more ado the entire case can be swung over to starboard on its hinges, when the removal of the valves becomes a matter only of seconds. In order that no dismantling of the driving shaft be necessary, a universal joint is introduced in the vertical, skew-gearing at the top and bottom, which transmits the motion from the mainshaft to the camshaft. An extension of the camshaft at the forward end carries the contact breaker for the high-tension ignition, and if a magneto be employed it is mounted on a bracket at the rear end and driven by spur gearing off a similar extension. Large inspection doors are fitted to the crank chamber, rendering the adjustment of the main bearings or big ends a simple matter, and permitting also the withdrawal of the piston and connecting rod complete if such need should arise. On the port side hopper-shaped attachments, fitted with lids fastened by a fly-nut, are provided for the replenishment of oil in the sump or for a cursory inspection. Cylinders are cast in pairs for the four-cylinder engines, and in triplets for the six-cylinder models. Between all the crank throws there are large bearings. Lubrication is forced, the oil pump, which is skew driven at the forward end of the engine, drawing its supply from a well in the crankcase and distributing it to the main bearings, whence it flows through the hollow crankshaft to the big ends and through the connecting rods up to the gudgeon pins. Another example of accessibility is afforded by the generous provision of core panels in the cylinder castings, whereby the jackets can, when necessary, be thoroughly cleaned. A gear pump maintains the water circulation round the jackets and exhaust pipes. Hot air is drawn in over the exhaust pipe to the automatic carburetter. The throttle is regulated solely by hand, although a governor can be fitted if desired, place being found for it on the vertical shaft that operates the valve gear. All moving parts are balanced. Five standard models are built, one series including two, four and six-cylinder engines of

Fig. 20.—Maudslay valve gear

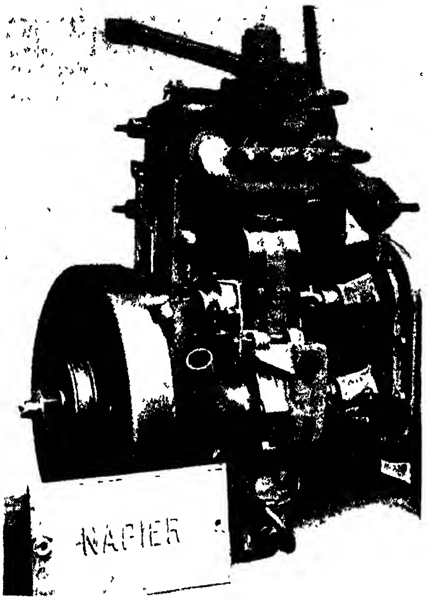


Fig. 21.—The enclosed Napier engine.

20h.p., 40h.p. and 60h.p. respectively, and the other being composed of two and four-cylinder motors of 15h.p. and 30h.p. respectively, all running at 900 revolutions per minute

The Napier Motor.

In the latest series of engines designed by the Napier firm there is a thorough and well-studied system of encasing all working parts in an ingenious manner that amply provides for accessibility. It is also noteworthy that a small model has been introduced, this being a two-cylinder 10h.p. which forms one of the best and neatest patterns of this power on the market. In the design and construction special attention has been paid to silence, not merely silence of exhaust, but silence of all moving parts. Both cylinders are cast in one piece in the 10h.p. model, illustrated in Fig. 21. Both inlet and exhaust valves are on one side, with the tappets and their guides, the valve stems and their springs completely enclosed in an oil-tight case, access to which is obtained by the large panel, shown removed and at the base of the engine in the illustration. On the same side and driven off the camshaft by over-and-under spurwheels are situated respectively the magneto and water pump. This gearing is also enclosed in an oil-tight case to which access can readily be obtained. The single central induction pipe and the branched exhaust outlet are bolted down in a handy manner. Although the automatic carburetter is situated low down on the opposite side, the mixture pipe is brought up to a throttle chamber on top of the engine, which also forms an accessible position. Lubrication, following the invariable Napier practice, is effected under pressure from an oil pump drawing on a sump in the base of the crank chamber. The flywheel is fitted at the forward end of the crankshaft. With the exception of the latter feature, the larger Napier models possess the same characteristics. The sizes run from a 15h.p. four-cylinder to a 90h.p. six-cylinder, and include a 26h.p. four-cylinder and two six-cylinders of 45h.p. (see Fig. 22) and 65h.p. respectively. On the two-cylinder and four-cylinder motors the magneto automatically produces the advance or retard without any hand control, but all the six-cylinder engines are fitted with hand regulation to the synchronised ignition system, in which one distributor and one make-and-break serve to operate the firing in all cylinders, perfect timing thus being insured. These same models are also more refined in details, there being, for example, the hydraulically governed carburetter, which is exceedingly sensitive to variations in load and varies the mixture almost instantaneously over wide changes of speed. It is the claim of the Napier company that by extreme attention to detail they provide a wonderfully controllable engine, and it is in pursuit of this refinement that they adhere more to automobile practice than to marine motor practice in the design of their boat engines. This new series has been christened the "Noiseless."

The Parsons Engine.

Owing to the design of the vaporising valve system, all the Parsons motors are suited to petrol fuel without any alteration in the details. The low compression required for paraffin being unaltered, the engines develop about the same power whichever fuel be used.

Rogers' Motors.

In addition to multi-cylinder units built up from the cylinders of 5h.p. and 8h.p., described in Class I., there is a two-cylinder motor of 8h.p. included in the Rogers' list, and similar engines of four or six cylinders of 16h.p. and 24h.p. respectively. Except that the cylinders are cast in pairs, these models possess all the same features as the whole range of Rogers' engines, the type of which is described in Class I.

The Scout Engine.

A couple of two-cylinder motors of 8h.p. and 12h.p. respectively, and a couple of four-cylinder engines obtained by duplication of those mentioned, forms the range of Scout multi-cylinder models. In detail the design conforms to the small engine described under the same name in Class I., the only departure being the adoption of five main bearings in the four-cylinder motors.

A Well-enclosed Engine.

Only two Simms models are now made for marine work specially, although the series built up from cylinders developing 6h.p. each is applied to the same purpose at reduced speed. The smaller marine motor, which is of 28h.p., and designed to run at 750 revolutions per minute, has four cylinders cast in pairs, with the valves all on one side. All bushes and bearing surfaces are made particularly large, and the design in general has been conceived for continuous running at full load. All gearing is enclosed, and Simms' high-tension magneto ignition is fitted as a standard. The only distinctive feature of this and the high-speed series is the provision for removing the valve-spring cotters by a lever pivoted to a pin on the cylinder casting. In the 100h.p. model, which runs at 700 revolutions per minute, all the valve gear is mounted on top of the engine, where every detail is rendered instantaneously removable. The valves and their seatings are each contained in cages, and by the disposition of handy pins the valve rockers can be easily displaced. Over each cylinder is fitted a hood to protect the valve gear. A centrifugal governor controls the speed by throttling, which is also under hand regulation. The crank case is amply provided with hand holes. Lubrication is forced, the crankshaft and pins being drilled. Simms' high-tension magneto ignition is, of course, fitted.

The Standard.

When these engines, which are fully described in Class IV., are intended to run on light spirit the heavy-oil vaporisers are replaced by a patent spray carburetter with a regulated feed, and not provided with the usual float-feed chamber. It is claimed to be free from flooding troubles, and is, of course, independent of the pitching or rolling of the boat.

Thornycroft Engines.

In the latest models there is not much departure from the previous practice of the firm, but by means of a longer stroke the power developed from cylinders of the same bore as hitherto has been noticeably increased. The two-cylinder engine, illustrated in Fig. 23, thus gives 18h.p. at 950 revolutions per minute instead of 13h.p. at 1,000 revolutions per minute as in the previous models, although the cylinders have the same bore. All the better features of marine practice are embodied in the design: large crankcase doors, enclosed gearing, cleaning panels to the cylinder jackets, forced lubrication and water-cooled exhaust expansion box, for example. The valves are on opposite sides. Low-tension magneto ignition is the standard, and the timing is fixed. The control is thus simplified to the throttle lever, which, if specially ordered, can be connected also to a centrifugal governor. A rotary gear pump maintains the water circulation. As fitted in the illustration, the engine is adapted for running on either petrol or paraffin (see Class IV.). A four-cylinder 36h.p. engine of the same type is also made. The next series includes a two-cylinder and a four-cylinder model, developing respectively 26h.p. and 53h.p., both at 750 revolutions per minute. Above these comes the four-cylinder 105h.p. motor, illustrated in Fig. 24, and turning at 700 revolutions per

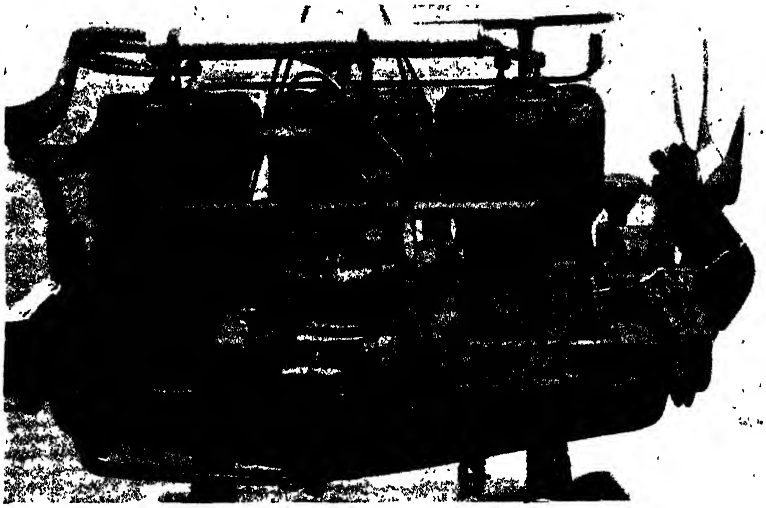


Fig. 22.—Napier 45h.p. six-cylinder engine.

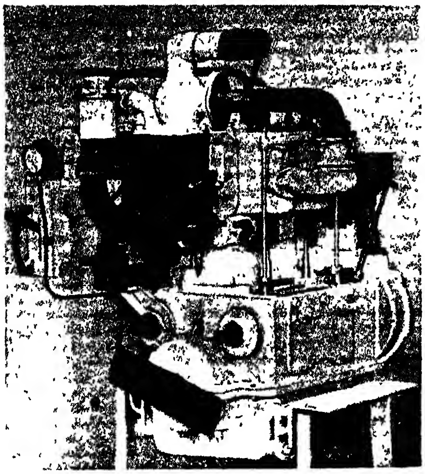


Fig. 23.—18h.p. Thornycroft.

minute. This is designed with all the valves on one side, including the auxiliary starting valves, which admit compressed air for setting the engine in motion. There is one of these valves to each inlet-valve chamber. Normally they remain inoperative. For starting they are brought into operation by the rod seen on the exterior of the crankcase in the illustration and on which are mounted four bell-cranks, which draw slides into the gaps that normally exist between the starting valve tappets and the valve stems, thus enabling the valves to be lifted by the motion of the third set of cams with which the camshaft is provided. It is a simple arrangement, with nothing to give trouble. The compressed air is admitted by a branched pipe to each double-inlet valve chamber. A small hand wheel fitted to the after starboard end of the engine controls the rod that throws the valves in or out of action. In this model the low-tension magneto ignition can be controlled, the igniter actuating rods, one to each pair of cylinders passing up through the valve chambers, being driven by skew gearing off the camshaft and, therefore, giving advance or retard as they are turned spirally by the timing rod seen alongside the crankcase in the illustration. This engine also is shown with the paraffin vaporiser that serves both for petrol and paraffin, but enables the engine to develop only 85h.p., instead of 105h.p., as when the combustion spaces are suited for petrol alone. Except that high-tension ignition is fitted also and that the throttle and auxiliary air inlet are separately controlled, the remaining details are the same as in the smaller type. The largest and most powerful of the Thornycroft models is the eight-cylinder 400h.p. engine. This is exactly similar to the 300h.p. paraffin motor described in Class V., except for slight modifications of the induction system. If petrol alone be used, two float-feed carburetters of the ordinary pattern are fitted, one to each four-cylinder unit.

The Wear Motor.

Although it is not long since this name was introduced to the marine motor world, it has already gained a considerable reputation. The manufacturers employ a number of their own motors in their salvage work, and seven were used in the operations to recover the "Gladiator." There are no specially unusual features in the design of any of the Wear types. They all run at a moderate speed. In the small series, which comprises sets with one, two, three or four cylinders, each developing about 2¾h.p., the revolutions per minute number 750; in the next series, which includes also a six-cylinder engine, the normal speed is 600 revolutions per minute,

Fig. 24.—A 100h.p. marine set.

each cylinder giving 4h.p.; and in the larger series, each cylinder of which is rated at 9h.p., the speed is kept down to 500 revolutions per minute. In addition there is a special series for heavy duty, giving 16h.p. per cylinder at 400 revolutions per minute. Cylinders are cast separately with all the valve gear on one side. Very large inspection doors are fitted to the crank chamber, these covering the whole of one side from the shaft line to the top of the case. Bearings are fitted between all the crank throws, and splash lubrication has been adopted. In the design of the connecting rod small end the impossibility of preventing wear has been recognised, and large adjustable bearings have been provided, the gudgeon pin being fixed by through bolts that extend to the bottom of the piston trunk to facilitate removal. Plunger pumps are used for the water circulation, and similar ones are fitted for the bilge draining.

Class III.

The following petrol two-stroke engines are dealt with:

Ajax.
Boulton and Paul.
Day Automarine.
Dolphin.
Fairbanks.
Fairbanks-Morse.
King.
Mitcham.
Popular.
Reliable.
Standard.

An Example of Air-scavenging.

Amongst the numerous attempts that have been made to improve upon the two-cycle engine in its simplest form, one of the most interesting is that of Bamford's air-scavenging action, which is embodied in the design of the Ajax motor. It is always said that the principles of the two-stroke cycle prevent the exhaust from being so thoroughly cleaned out of the cylinder as it should be, and, further, that the inrushing mixture, being under pressure from the crankcase, partly escapes through the exhaust port before this is closed. These objections have attracted the attention of many minds, but nothing simpler in relation to its effectiveness than Bamford's scavenging has yet been devised. Its method of operation lies in the aspiration of pure air into a chamber intermediate between the cylinder and crankcase, and the subsequent sweeping of this air into the cylinder by the rush of mixture from the crank chamber. Thus, in Fig. 25, whilst the gas mixture is being drawn into the base chamber through a non-return valve in the ordinary way, pure air is aspired into the annular intermediate chamber through a non-return valve. The annular chamber can be clearly seen to communicate with the cylinder, but the diagram does not as clearly demonstrate the connection with the base chamber. On the down stroke of the piston the exhaust port first opens to permit the burnt gases to escape, but the inlet port commences to be uncovered very shortly afterwards, and is fully open almost as soon as the exhaust port. Only one passage exists for the transference of the compressed mixture from the crank chamber to the combustion space, and that passage lies through the intermediate chamber. Driving the layer of pure air before it, the mixture rushes into the cylinder, and it is clear that any loss that must occur will be of pure air only. Moreover, the opening of the ports is calculated to ensure that a plenitude of air shall pass out through the exhaust port to scavenge all remaining burnt gas out of the cylinder. Control is effected by a special throttle operating both on the supply of explosive mixture and on the supply of scavenging air. A float-feed carburetter is employed instead of the more customary vaporiser valve. Standard ignition is by the high-tension accumulator and coil system. Lubrication forms a special feature, the oil being fed under pressure to the main bearings, connecting-rod ends and cylinder walls by pressure obtained from the scavenging air through a non-return valve. Each sight feed is adjustable. In order to reach the crank and gudgeon pins the oil travels through ducts bored in the crankshaft and connecting rod. A rotary water pump is employed, and the circulating water passing out from the cylinder jackets is sprayed into the exhaust box to cool the burnt gases. As will be noticed from the diagram, large balance weights are added to the crankshaft in order to reduce vibration to a minimum. Standard models include two series of single, double, and treble-cylinder engines, developing respectively per cylinder 5h.p. and 7½h.p., the corresponding normal speeds being 650 revolutions per minute and 550 revolutions per minute. A single-cylinder 3h.p. and two-cylinder 6h.p., designed to turn at 750 revolutions per minute, complete the list.

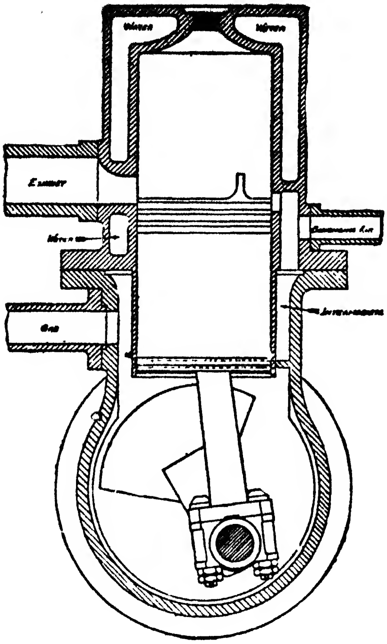


Fig. 25.—The Ajax motor.

A Reversible Engine.

In the Boulton and Paul motors, as in most engines of this class, the crank chamber is used as the pump-compression chamber, leakage being guarded against by the long bearings shown in Fig. 26. Although only a small inspection hole is fitted to the crankcase, this is no disadvantage to a two-stroke engine when, as in the present case, access to the crank chamber can be obtained by the removal of the end plate next the flywheel. A simple cylinder casting is used, with the water-cooled exhaust expansion box bolted to it. Not only is the water led away from the cylinder jacket through this box, but a water spray is arranged into the exhaust chamber, a method that by cooling the waste gases so thoroughly conduces to efficiency by the reduction of back pressure. The water pump, which is of the plunger type, is bolted to the rear end of the cylinder, the ram being operated by an eccentric rod off the main shaft. A grease cup is fitted to the eccentric strap. A stuffing gland with lock nuts permits the pump to be kept tight. High-tension accumulator ignition is employed, the contact breaker being fitted on the forward end of the crankshaft. It consists merely of a shell containing a contact segment, the contact pin, which is stoutly made and easily renewable, being fitted into the flywheel, where it is quite accessible. The timing is regulated by the transverse movement of the attached lever, which bears at the top a switch. As the engine is required to reverse, the current is broken at the switch, the lever thrown hard over against the direction of rotation, and the switch again closed. Two grease cups are fitted for the main bearings, and a sight-feed oil drip for the cylinder. By means of directing grooves cut in the piston and leading to a hole drilled through the centre of the gudgeon pin, oil runs through chases on the surface of the pin and in the bearing to lubricate the small end in addition to the splash. A useful feature for the conservation of the proper compression is the fixing of the diagonally-lapped piston rings by means of pins. Stock sizes are the single-cylinder motors of 2h.p., 3h.p. and 5h.p. and the double-cylinder 10h.p., the other models being the two-cylinder 8h.p., 15h.p. and 30h.p., the three-cylinder 15h.p., and the four-cylinder 20h.p. and 30h.p., all at 650 revolutions per minute.

The Day Automarine Sets.

In the latest designs the engines that bear the suggestive title Automarine have been improved in detail. A typical model, the 10h.p. double-cylinder, is illustrated in Fig. 27. Both cylinders are cast in one piece, with a single, central gas inlet and a corresponding arrangement of the exhaust outlet. In this manner an excellent induction of the mixture is obtained, for the explosive gas is drawn into a chamber between the two cylinders, and because both draw their supply from this common space it is practically impossible for one to get a different mixture to the other. A float-feed carburetter, provided with a silencing hood to deaden the noise of the inspiration of air, is fitted as shown. This in itself is an uncommon but desirable accessory of two-stroke engines. The principle which Mr.

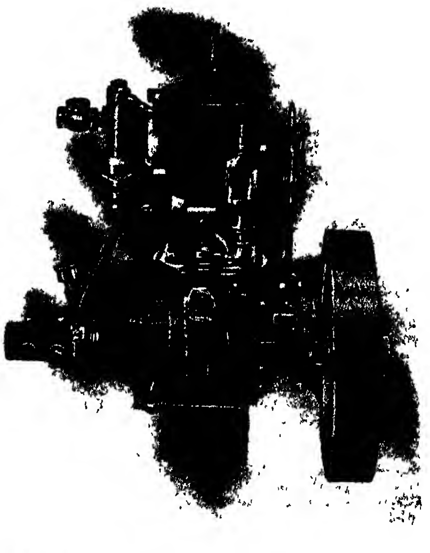


Fig. 26.—The B. and P. reversing engine.

Day, the designer of this engine and the absolute originator of the valveless two-cycle motor, adopted as far back as 1890, of admitting the lubricating oil with the gas mixture, is utilised in this model. It possesses the very valuable feature of rendering neglect of the oil system practically impossible. A sight-feed drip lubricator, placed well in view at the top of the engine, regulates the supply, and by this system lubrication is furnished to all the working parts except the main bearings, which are fed by grease cups. A bracket, bolted to the top of the crankcase, carries both the water pump and the contact breaker, the spindle for which is driven by a chain off the main shaft, and has proved quieter than if operated by spur gearing. A large cast-iron expansion box is fitted to the exhaust side of the engine, and into the cooling jacket of this the circulating water from the cylinders is discharged before being passed outboard. The control provided by the throttle and the ignition gives a very effective range of speed —from a comparatively small number of revolutions per minute up to the maximum of 700r.p.m. A full range of models of different powers is provided, all possessing the same characteristic features of the particular engine herewith described.

Dolphin.

This engine, the most recent addition to the two-stroke class, has at the time when these chapters are being compiled only just been placed upon the market. It differs from the others in having a separate pump for compressing the mixture before it enters the cylinder. Pump and cylinder are set diagonally at rather less than a right-angle, and, being slightly staggered in respect to each other, both connecting rods are brought almost in the same plane, but the pump rod, instead of bearing on the crank pin, is linked to a pin on the upper half of the big end of the driving connecting rod. Owing to the angle between the pumps and working cylinder, the pump piston has a slight lead. It commences to draw in mixture from the carburetter before the piston of the working cylinder reaches the top of its compression, and completes half its travel before the working piston commences to descend. It therefore commences to compress its mixture when the working piston is halfway down the power stroke. The burnt gases pass out of the working cylinder through ports, as usual, and the mixture from the pump then passes through the delivery pipe to the automatic inlet valve situated in an air-cooled bottle on top of the working cylinder. The pump is at the top of its stroke when the working piston is halfway up the compression, and at that moment, therefore, the inlet valve closes, the pump commences another suction stroke, and the working piston continues to compress the explosive charge until it is ignited just before the top of the stroke. The working cylinder is water-cooled, and has a coned combustion space, to which the inlet valve bottle is attached. Ribs on the latter serve to cool it. Splash lubrication is employed, and high-tension ignition is fitted as a standard. Later reports of this engine will be interesting.

Fig. 27.—Automarine 10h.p. motor.

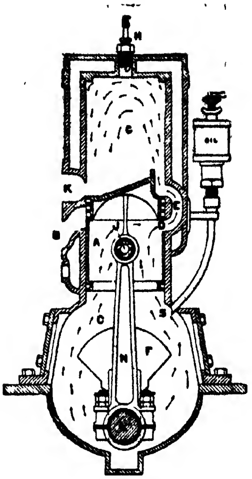


Fig. 28.—Section of Fairbanks engine.

An American Two-stroke Type.

A very wide range of power is provided by the Fairbanks engines, which are constructed on the three-port system. The cylinder is cast in one piece with the upper half of the crank-

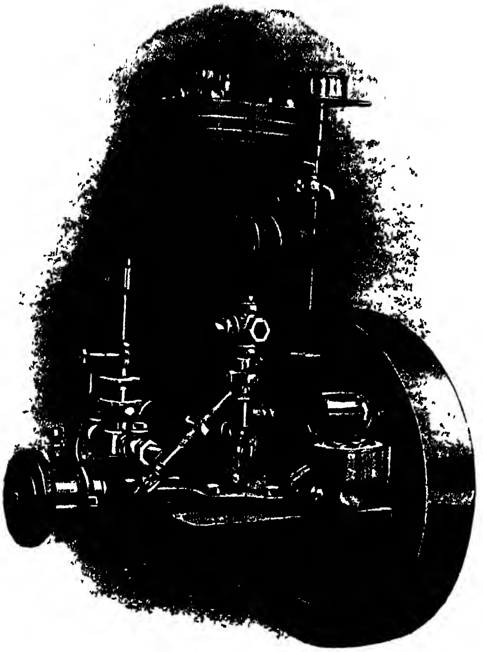


Fig. 29.—Fairbanks engine.

case. The water-cooled cylinder head, which is counterbored to leave a ring projection fitting closely to the cylinder wall to prevent the blowing out of the gasket, is bolted down by studs, and is also provided with two small lifting jack screws for the purpose of facilitating its removal. Both the exhaust pipe casting and the gas inlet pipe are water-jacketed, the former for cooling and the latter for warming. In all sizes the cranks are balanced. A novel form of piston is used, from which a two-fold advantage is obtained. Referring to Fig. 28, it can be perceived that the top of the piston is oblique to guide the burnt gases through the exhaust port, whilst the customary baffle is fitted next the inlet port. It is, however, in the arrangement of the port opening D that the novelty lies. This being cut in the piston trunk at a suitable height, not only can the compressed mixture find an easy path from the crank chamber into the combustion space, but the explosive charge being cool and sweeping past the gudgeon pin and piston top tends to reduce the heat in that part and thus to facilitate lubrication. A float-feed throttling carburetter is fitted to all models, and being of the automatic type confers a great advantage in economy, controllability and efficiency. An auxiliary air port is provided for running at low speeds. Hot air is taken into the carburetter from around the exhaust pipe. Lubrication, which is by splash, is rendered more effective by holes bored in the big end, the oil picked up by the big end itself, and by the balance weights being constantly fed in. Further, the sight-feed cup supplies a constant drip through the pipe S, which enters the crank-case over the crank-pin circle. The same cup feeds the cylinder walls and the gudgeon pin, the latter being hollow for the purpose. Grease cups are used for the main bearings, which are very long. On the three and four-cylinder engines forced lubrication is employed. This is effected by a series of small pumps in a tank at the side of the engine, the pump spindle being driven by a thin, round belt off the water-pump shaft. Over each small pump is a sight-feed glass and adjustment. In the single-cylinder

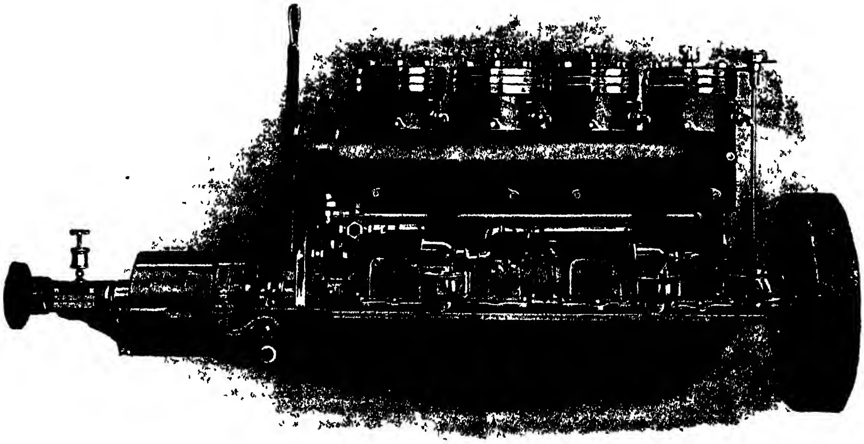


Fig. 30.—Four-cylinder 35h.p. two-stroke engine and gear.

engines the jacket water is circulated by a plunger pump operated by an eccentric rod, as in Fig. 29, where the plunger rod guide is also visible. In the same illustration can be seen the water connection from the exhaust pipe jacket to the inlet pipe jacket. Ignition is by high-tension coil from an accumulator, the contact breaker being mounted on a vertical, bevel-geared spindle at the forward end of the engine, and being at the level of the cylinder head, it is quite accessible. Great attention has been paid to insulation. A hood is fitted over the sparking plug. The main portion of this cup is made of porcelain. A recessed neck on one side permits the introduction of the clip terminal, and this connection being covered by a piece of rubber tubing, the insulation is most effective. On the multi-cylinder engines recourse is made to a rotary pump for the water circulation, spur gearing at the after end of the engine being used for the drive. In adding that handholes are fitted to each crank chamber on both sides, the description of one of the most refined two-cycle engines on the market is completed. A four-cylinder 35h.p. engine is illustrated in Fig. 30, which shows the oil-pump box; Fig. 29 refers to a single-cylinder 8h.p. motor. The models include single-cylinder engines of 6h.p. and 8h.p., turning at 900 revolutions per minute and at 750 revolutions per minute respectively; two-cylinder engines developing 12h.p. and 16h.p. at the same respective speeds; three-cylinder units giving 20h.p. and 25h.p. also at the same respective speeds; and a four-cylinder 35h.p. motor turning at 750 revolutions per minute.

The Fairbanks-Morse Engine.

An excellent series of refined engines, in two patterns, is made by this firm, in addition to its four-cycle types. In the first pattern the cylinders are cast separately with the upper half of the crankcase, in which large hand holes are fitted, the water-cooled heads being detachable, while in the second pattern they are cast solid with the cylinders. The crankshaft is balanced, the exhaust pipes are water-jacketed, and both the pump and contact-breaker gearing is completely enclosed. The inlet and exhaust pipes are on the same side, and bolted to the cylinders by a common yoke, with only one bolt per cylinder. A single carburetter of the float-feed pattern, with throttle, is fitted alike to one, two or three cylinders. High-tension coil and accumulator ignition is employed, the contact breaker being mounted accessibly on a vertical spindle forward. Sight-feed lubrication is fitted to the cylinders, grease cups to the main bearings, and splash for the connecting-rod bearings. The solid-head models are a single-cylinder 3½h.p. and a two-cylinder 7h.p., turning both at 650 revolutions per minute; whilst the detachable-head series includes a single-cylinder 6h.p., a two-cylinder 12h.p., and a three-cylinder 18h.p., all running at 600 revolutions per minute. The latter is illustrated in Fig. 31 with the carburetter removed.

An Original Motor.

Several divergences from usual two-stroke practice mark the King engines, but these occur mainly in the multi-cylinder models. Common to all sizes is the casting of the upper half of the crank chamber integrally with the cylinder and jackets, but separate from the uncooled head. Low-tension ignition by accumulator and trip igniters is adopted. The cylinder is lubricated by a sight-feed oil cup, the splash well in the crank chamber being replenished by a separate oil cup. The main bearings are fitted with grease cups, the grease being retained in the bearings by the compression stuffing boxes. The usual plunger pump, driven by an eccentric off the main shaft, is used for the water circulation. These features are common to all King engines. In the multi-cylinder sizes, however, the vaporiser valve of the single-cylinder motor is replaced by an ordinary float-feed carburetter, and the trips for the igniters are placed all on one shaft running in bearings on the walls of the cylinder jackets, where adjustments can easily be made. It is driven by a vertical spindle and bevel gearing off the main shaft, and one lever controls the ignition of all cylinders in what is probably the simplest method possible with low-tension ignition. The full range includes a series of one, two, three and four-cylinder engines, developing 6h.p. per cylinder at 450 revolutions per minute; another series of one, two and three-cylinder motors giving 4½h.p. per cylinder at 500r.p.m., and a small 2h.p. single-cylinder running also at 500 revolutions per minute.

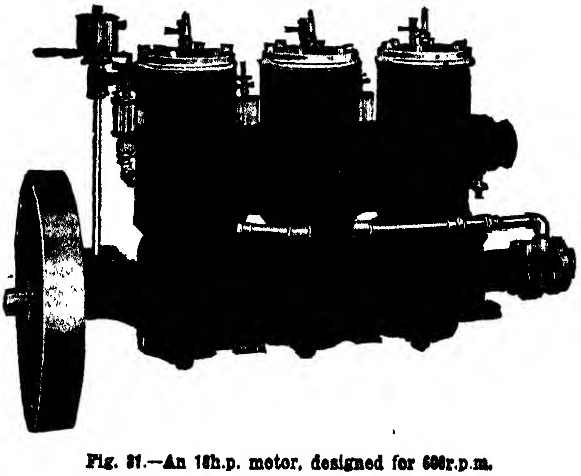


Fig. 31.—An 18h.p. motor, designed for 600r.p.m.

Fig. 32.—A Mitcham marine set.

Mitcham Motors.

Of two-stroke engines, the Mitcham F. and B. must be reckoned among the most widely used in this country. Although possessing the simplicity inherent to the two-cycle motor, it does not suffer from excessive simplicity. It has a refinement of detail which some examples of this type do not possess, and it is a thoroughly marine job, as its adoption by the National Life-boat Institution testifies. A general idea of all the models is given by the illustration of the two-cylinder 7h.p. pattern in Fig. 32. Each cylinder forms a unit in itself with its own crank chamber, being cast in one piece without the cylinder head and without the end plates of the crank chamber, but with the inspection holes in the base. This frame, as it may be called, is the basis of each cylinder unit. When the water-cooled head is bolted down and the moving parts fitted, with the end plates of the crankcase in their proper position, bearing the crankshaft, the unit is complete but for the piping and ignition. The ports are, of course, cast in the frame, and there is only to fit the vaporiser to the inlet and the exhaust pipe to the outlet. Low-tension ignition is employed as a standard. The igniter plug is ground to a fit in the cylinder head, and is operated by a revolving spindle, driven by bevel gear off the crankshaft, and passing up through the water jacket in a water-tight tube. The trip gear of the igniter has a very rapid action. For two-cylinder engines the spark is obtained from a battery, but for larger motors a magneto is used. In multi-cylinder motors the timing of the ignition is controlled by a single rod running along the heads of all the cylinders and moving simultaneously the position of all the tripping cams. As this engine is intended to run only in one direction, the igniter cams are worked over little clutches, which throw the ignition gear out of action if the engine starts in the wrong direction. Over each cylinder head, protecting the ignition from spray and damp, is a neat cover, which is distinctive of the Mitcham design. Each vaporiser valve is governed, not by a variation of the air supply, but by a needle valve in the petrol pipe to choke the supply of fuel, the quantity of air drawn in remaining constant. This system prevents an accumulation of petrol in the base chamber. A fitting that is seldom found in these vaporisers or generator valves is the connection of a hot air-pipe to the main air nipple, thus ensuring a warm air supply favourable to a good gas mixture. This heating arrangement is adjustable. A water jacket is applied to the exhaust pipes from the engine to below the floor level, and the water is then discharged overboard through the silencer. All these engines run at the very efficient speed of between 450 revolutions per minute and 500 revolutions per minute, but a light-weight model for fast launches can be supplied to run at 900r.p.m. The powers vary from 2h.p. to 33h.p. in multi-cylinder sets built up from cylinders giving 2h.p., 3½h.p., 5½h.p., and 7h.p., a series of 16 patterns in all. Under Class V. will be found a description of the alterations made in these motors to suit them for the consumption of paraffin.

The Popular Motor.

Having a throttle fitted to the mixture pipe between cylinder and crankcase, these engines are almost exceptional in their class, for by far the greater proportion of two-cycle motors are not provided with this method of control. General opinion inclines to the belief that no greater degree of controllability is furnished by the throttle than by the almost universal regulation on the fuel feed, so far as this type of engine is concerned, but in the absence of any tests on this point it would be futile to declare any definite opinion. In any case it is certain that no disadvantage can accrue from its adoption, and it must merely be conceded as a detail to be settled by the designer's inclinations. The usual crankcase compression is used, and an ordinary vaporiser valve is fitted with hand regulation on the fuel feed. It is only in the addition of the throttle that the design differs so markedly. Each cylinder is cast separately from the head, but in one piece with the upper half of the crankcase, on both sides of which small inspection panels are arranged, those on the port side having the vaporisers attached. Compression grease cups are screwed to the main bearings, which are channeled to distribute the grease. Splash lubrication is relied upon for the connecting-rod ends in the smaller motors, but in sizes above 8h.p. independent lubricators are used for the crank and gudgeon pins, which in all models are provided with oil ways. Ordinary drip feed is fitted for the cylinder walls. Low-tension ignition from accumulators has been adopted, but magneto can just as easily be supplied. In the single-cylinder models the trip rod is operated directly by an eccentric, but for two or more cylinders an exterior spindle, common to all, is used for the purpose, the eccentric then driving this at the after end. The plunger pump lies horizontally on the bed plate, and at right angles to the crankshaft, off which it is driven by an eccentric rod. Single, double, three and four-cylinder units of 8h.p. per cylinder at 400 revolutions per minute form the main series of the Popular engines, but single-cylinder

engines are also made. On going to press we learn that these engines are being entirely redesigned, so that the above particulars are subject to correction.

An Engine with a Cross-head.

Though altered in design, the present type of Reliable motors retains the essential characteristics of the pattern which has for several years been acknowledged as among the theoretically most correct of all two-stroke engines. It is notable in possessing a pump chamber that is quite independent of the crankcase. The fundamental principle can be clearly traced in the section, Fig. 32a, illustrating the details of the three-cylinder 30h.p. model. The mixture from the carburetter (c)—which is in this case the Universal paraffin carburetter—is aspired into the lower portion of the cylinder through the port (g) as the piston ascends. The lower portion of the cylinder forms a separate chamber, bounded at the bottom by a plate, and at the top by the piston and surrounded by the cylinder walls. When the piston reaches the top of its stroke, the working charge for the next explosion is all contained in this chamber under the piston. On the down travel the piston, as usual, first uncovers the exhaust port, allowing the burnt gases to escape, and then immediately afterwards the inlet port is opened, whilst a port (h) in the piston trunk simultaneously registers with a lower port (d) in the cylinder, thus permitting the compressed charge to rush through the passage (f) into the cylinder. The cycle is exactly the same as in other two-stroke engines. Obviously, the double-action cylinder requires the use of a piston rod and crosshead. The disposition of this can be clearly seen in the illustration. The piston rod is bolted to the piston, and passes through the lower cylinder cover in a stuffing box. The crosshead guides are machined from an integral portion of the upper crankcase casting. Whenever adjustments need to be made to the brasses—and it will be but seldom, because they are proportioned to their work—the tightening can be effected through the large inspection doors of the crankcase. In this manner the brasses of the main bearings, of the top and bottom ends of the connecting rods, and of the crossheads are all accessible, and the guides and guide shoes can also be immediately

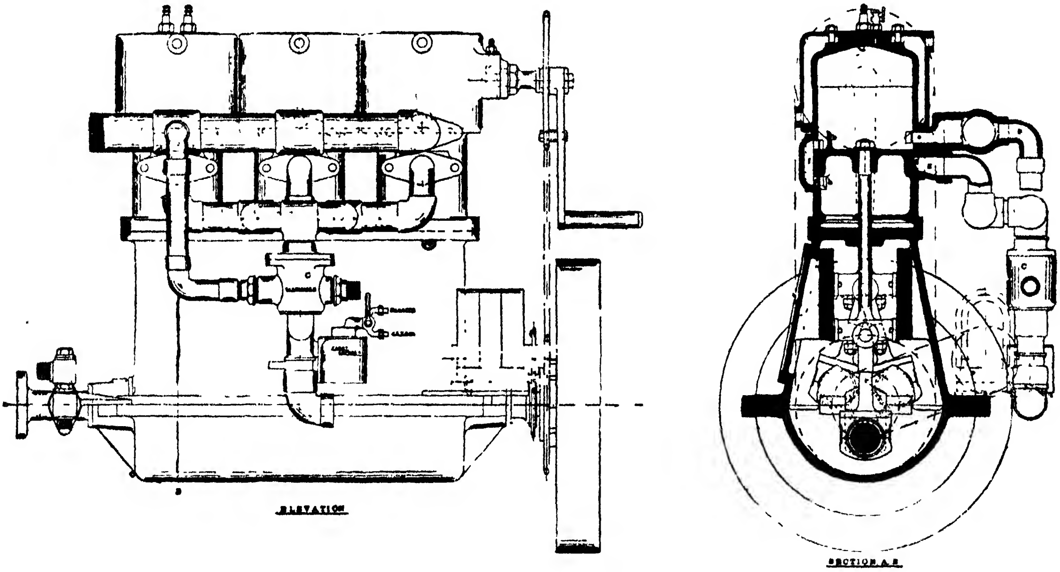


Fig. 32a.—The Reliable motor, showing crosshead guides, etc.

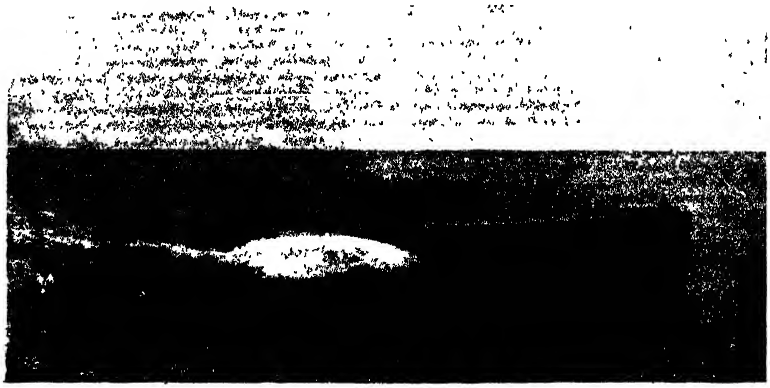
reached without the removal of any cylinder or cylinders. Another novel feature of the design is the casting of the water jackets separate from the cylinders, to which they are bolted by Muntz metal studs in the crown, the jacket joints being ground true. This construction enables not only the cylinders to be machined inside and out, thus ensuring even thickness of the walls, but also ensures a clear annular space for the water circulation and provides a means of cleaning out any sediment. The inlet ports in the cylinder walls, being covered by cast-iron, removable doors, can be accurately machined instead of being cast with more or less accuracy according to the amount of care bestowed on the casting. The induction piping, further, being screwed into flanges bolted to the cylinders, enables the

mixture intake port to be just as mathematically correct in position and size. Dual ignition is fitted, both sparking plugs being in the cylinder crown. The magneto is driven by a chain off the main shaft at the forward end. Splash lubrication is employed. For the water circulation a plunger pump driven by an eccentric is used. It will be plain that by the abolition of crankcase compression a much more compact engine is obtained than is possible with the ordinary type of two-stroke motor, each cylinder of which has its own crank chamber and very long bearings to prevent leakage. No necessity arises in the Reliable system for introducing any feature into the construction of the crankcase other than is found in four-cycle engines, and, of course, one crank chamber serves for many cylinders. For the benefit of those who have no knowledge of steam practice, it may be added that the piston rod and crosshead form an inseparable feature of the construction of all steam engines of the double-acting type.

The single-cylinder models develop $3\frac{1}{2}$h.p. and $6\frac{1}{2}$h.p., and the two-cylinder engines 7h.p. and 12h.p., whilst larger sizes from 18h.p. to 75h.p. are also made.

The Standard.

There is nothing very unusual about the Standard motors of this type, but they represent an excellent example of careful preparation for marine work. The cylinder is cast separately from its head, and the crank chamber open-ended. In the uncooled cylinder head is situated the igniter gear of the low-tension firing system, the trip being operated by a spindle driven from bevel gearing on the crankshaft and passing up through the cylinder jacket. Over all is a protecting hood, fitting neatly to the top of the cylinder. A patent spray carburetter, without a float-fed supply chamber supplies the mixture, which passes to the crank chamber through a passage in the hot-cylinder walls. Compression grease cups and oil lubricators, with splash in the crankcase, ensure proper lubrication. On the single-cylinder engines the rotary water pump is chain driven, but on the multi-cylinder models both magneto and water pump are gear driven. Single-cylinder motors of 2h.p., 4h.p. and 6h.p., and two-cylinder units of 8h.p. and 12h.p., form the chief patterns of the England Standard, but larger engines are also constructed.



"Sizaire-Naudin."

Class IV.

The following paraffin high-speed engines (single and multi-cylinder) are dealt with:—

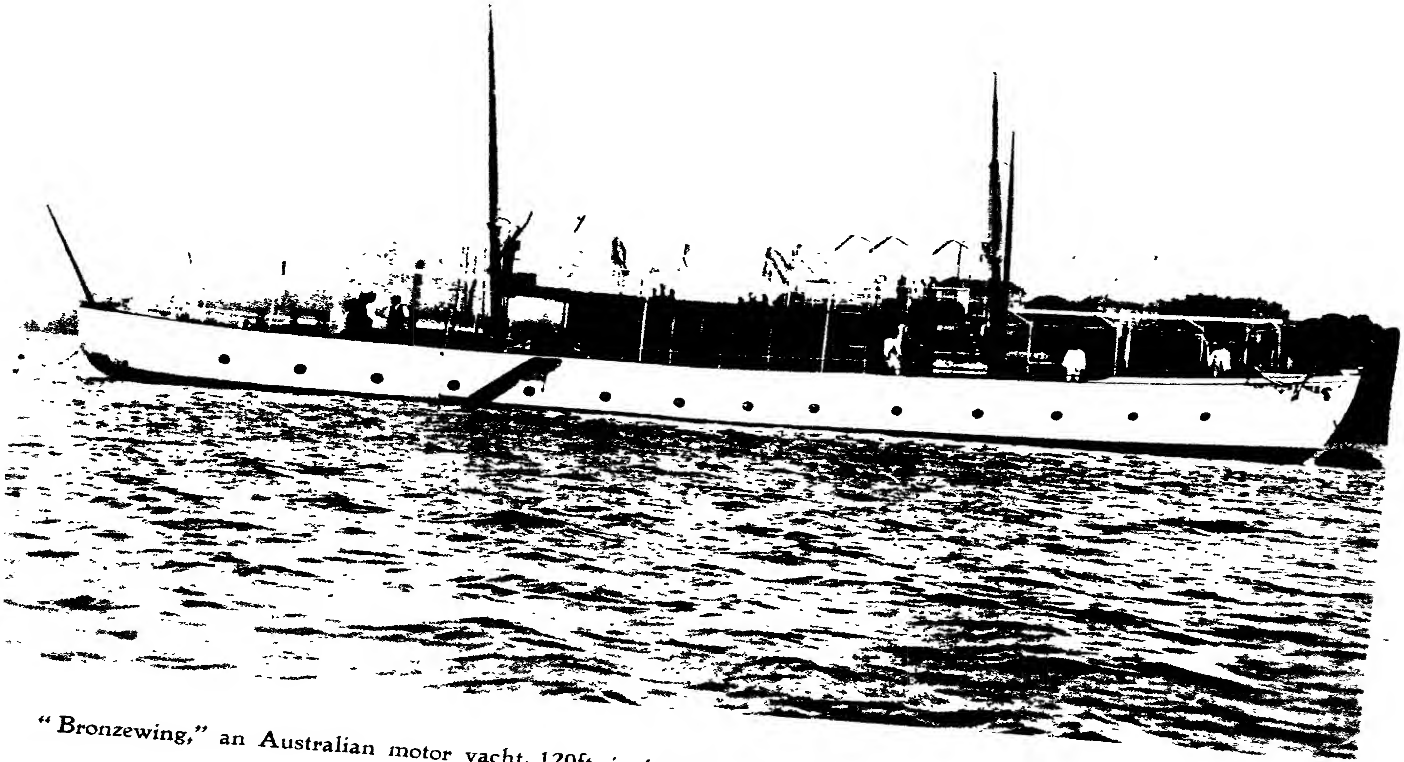
Barcar.	Seal.
Gardner.	Standard.
Kelvin.	Thornycroft.
Parsons.	Wear.
Pasley.	Woodnutt.

Barcar.

Only one model for paraffin fuel is made, and this differs in design from the petrol engines of the same name, described in Classes I. and II. It is a single-cylinder motor, developing 6h.p. at 800 revolutions per minute. The vaporiser is of a simple pattern, exhaust heated when the engine is running, but requiring a blow lamp for the initial warming unless petrol be used for starting up. In place of the usual throttle there is a variable lift device on the inlet valve, and this is controlled both by hand and by the governor. Low-tension magneto ignition is employed on this model, but the remaining details are similar to those of the Barcar petrol engines.

The Gardner Engine.

It would be difficult to name an engine that has obtained a wider reputation than the excellent Gardner paraffin motor, which is to be found in vessels of all types all over the world. It has been on the market a number of years now, and has, of course, thus had perhaps the greatest opportunities for becoming known. Yet it could never have earned its renown had it not been a thoroughly serviceable and reliable engine. There exists a rather widespread impression that the design is complicated, but this is based on the very unsatisfactory grounds that an illustration, such as Fig. 33, which represents a two-cylinder 10h.p. model running at 800 revolutions per minute, shows a number of fittings that are not customary in marine motors. If the details be examined, it will, however, be found that they possess no intricate parts. For example may be cited the hood that deadens the noise of the air being sucked into the inlet valves. This is a mere box. Again, the domes that steady the supply of oil in the pipes feeding the vaporisers loom large in the illustration, but they are only shaped pieces of metal with no moving parts and subject to no strain. Thus it is with the entire design: there is no complication. In referring particularly to the accompanying illustration it will be noticed that each cylinder is cast separately with the exhaust valve on the port side and the vaporiser on the starboard side. Each vaporiser has a burner underneath whereby it can be warmed for starting up. The burners are protected from draughts and wind by screens, a door in the front of which gives access for lighting them and for inspecting the heat of the vaporiser walls. Paraffin is fed to them under pressure, and they are regulated by cocks in the supply pipe. When the engine is turning the oil is sucked into the vaporiser when the automatic inlet valve opens, and being immediately vaporised in the hot chamber forms a rich mixture with the small quantity of air admitted there. As the piston descends and the suction grows stronger, a snifter valve in the centre of the combustion head also opens, admitting a small quantity of air to mix with the gas already in the cylinder and permitting a few drops of water to enter. On the compression stroke the whole mixture in the cylinder is rendered uniform, and at the top of the stroke the spark from the low-tension magneto ignites the gas and explodes it, the water deadening the knock that might then otherwise occur. When the engine has run for a couple of minutes the lamps can be turned out, and the vaporisers will then maintain their heat from the explosions, being open to the combustion chambers. It is quite simple and there is no complication about the system, the main air inlet valves, the oil feed and the water for the cylinder drip through the snifter valves having all an automatic action. Governing is performed on the hit-and-miss system, the action of the centrifugal governor being to keep the exhaust valves closed until the speed returns again to the normal. The retention of the exhaust gases maintains the vaporiser hot during the idle strokes. This governor also controls the timing of the ignition, which can be regulated by hand independently. Splash lubrication is employed. The water, after passing round the cylinders, is discharged into the cooling jacket of the exhaust box. Several series of engines are constructed on the same general



"Bronzewing," an Australian motor yacht, 120ft. in length, and fitted with three 100h.p. Thornycroft motors.

lines and they cover a very large range of powers. There are sets of one, two, three or four cylinders, giving 5h.p. and 7½h.p. per cylinder respectively, the first at 800r.p.m. and the second at 750r.p.m.; and three other series that are mentioned in Class V. A type suitable for high-speed work is found in the four, six and eight-cylinder models that give 20h.p. per cylinder at 900 revolutions per minute. The largest of these have been installed in vessels belonging to a foreign navy, no fewer than eight of these 160h.p. eight-cylinder engines having been supplied for the purpose.

A Converted Petrol Engine.

When required to burn paraffin fuel, the Kelvin motors are slightly altered. The combustion space is changed and an exhaust-heated vaporiser is added with one spraying jet for each pair of cylinders. Water drip valves are also fitted to the cylinder heads. Starting is effected on petrol, but the light spirit does not burn very well when the vaporiser is heated up, and better running is obtained with the heavier fuel. All the Kelvin models can be altered in this manner.

A Concentric Valve Motor.

A peculiar disposition of the valves singles the Parsons engine out from all other marine paraffin motors in the same distinctive fashion as the inversion of the cylinder marks the Seal. From the accompanying diagram (Fig. 34) it can be gathered that the valves are combined, the exhaust valve being seated upon the tubular inlet valve. The exhaust gases pass through the centre of the latter and emerge through ports at the bottom of the valve, to pass away to the exhaust pipe. The incoming sprayed charge, impinging upon the hot barrel of the inlet valve, is vaporised at the moment before it enters the cylinder. When paraffin is being used there is no vaporisation in the carburetter, and no additional heat required for it; therefore, there can be no subsequent recondensation in pipes between the carburetter and the cylinder, nor can any liquid fuel reach the combustion chamber. The amount of heat is not so great that any prejudical effect is noticed if the engine be kept running on petrol after it has warmed up. In the latter case, warm air from near the exhaust pipe is supplied to the carburetter. Although it is easiest and handiest to start upon petrol, either by pouring a little spirit into the carburetter through a special filler or by the supply from an auxiliary tank, it is also possible to set the engine turning on paraffin. The carburetter employed is a Parsons adaptation of a Longuemare, designed to withstand initial heating with a blow lamp for starting on paraffin. An adjustable needle valve permits the variation of the jet orifice to suit the particular fuel used, but for starting on petrol the adjustment for the heavier oil need not be disturbed. Both inlet and exhaust valves are mechanically operated by separate cams, both valves lifting on the inlet stroke, the exhaust necessarily remaining seated on the inlet, but only the exhaust valve lifts on the exhaust stroke. One spring, cotter and washer serve for both valves. A view of the 7h.p. single-cylinder engine is given in Fig. 35, where the needle adjustment, spirit filler and adjustable air inlet of the carburetter are clearly shown. The method of driving the water pump by helical gearing is also visible in the foreground. An ingenious compression relief valve, which grinds itself in every time it is used, is fitted, the principle embodied being that the thread of the male stem is half the width of the female thread, and rotation beyond the closing point of the valve takes place each time it reaches its seat. All gearing is enclosed. Large inspection panels are fitted to the crank chamber in every

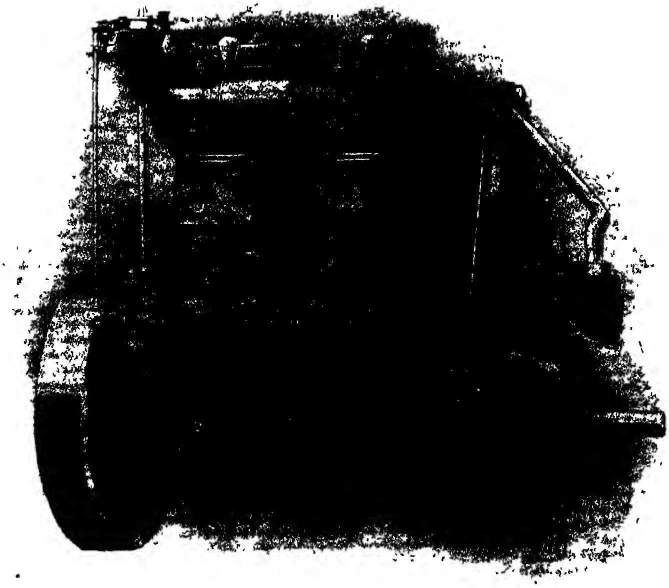


Fig. 33.—10h.p. Gardner motor.

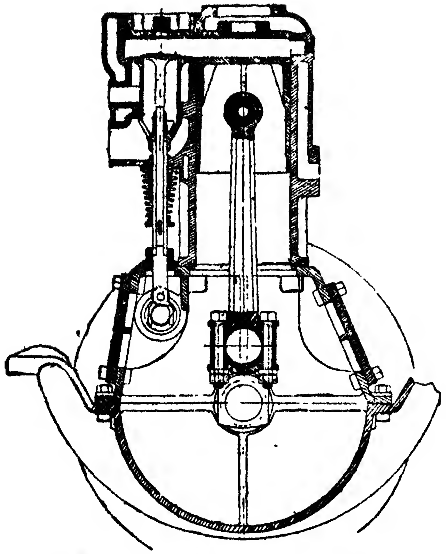


Fig. 34.—Section of Parsons motor.

model. In the multi-cylinder engines the exhaust branch pipe is arranged to allow for expansion when hot, and does not thus force the cylinders out of line. Splash lubrication only is employed, and high-tension ignition by accumulator and coil is the standard. In addition to the 7h.p. motor mentioned, sets of two, three and four cylinders are built up from the same unit to give 14h.p., 21h.p. and 28h.p. respectively at 700 revolutions per minute, and there are also three-cylinder and four-cylinder models, developing 45h.p. and 60h.p. respectively at 550 revolutions per minute. Reference is made to larger sizes in Class V. that covers engines turning at a slower speed.

Pasley Engines.

In general, the description of the medium-speed Pasley engines, described in Class V., applies to the high-speed models of the same firm. Low-tension ignition by means of a battery and intensifying coil is fitted as the standard, but can be supplemented or replaced by a magneto, the igniters being actuated off the camshaft. The valves are in this type situated in overhanging pockets, the camshaft being carried in bearings outside the crankcase and shoes being interposed between the cams and valve rods. In the single-cylinder patterns balance weights are added to the crank. One, two and four-cylinder engines are built up from a series of cylinders developing respectively 4½h.p., 7h.p., 10h.p. and 14h.p. at 1,000 revolutions per minute, and there is in addition a larger and heavier design giving 25h.p. at 750 revolutions per minute. The smallest cylinder has automatic inlet valves, but mechanically-operated valves are fitted to the larger patterns.

An "Overtype" Motor.

It is not surprising that the Seal is one of the best-known engines in the marine motor world, for it is of a unique type, and there is nothing like originality for the making of a wide reputation. Its peculiarity is the inversion of the cylinder and crankcase, the latter being on top and the former underneath. The combustion chamber, water jacket and port to the cylinder head are all contained in one base casting without any joint. The balanced crankshaft runs in phosphor-bronze bearings above the combustion chamber, and is enclosed in the dome-shaped crank cover that carries the lubricators for the bearings, crank pin, etc., as shown in Fig. 36. The crank dome cover can be removed with half the bearings for the inspection of the piston and connecting rod, without dismantling any other part of the engine. The whole of the valve gear, oil feed and ignition gear can be removed independently of the cylinder. Owing to the cylinder head being below the water line, when installed in a boat, and to the natural tendency of warm water to rise above the cold, the water circulation is automatic. A valuable feature of the design of the connecting rod is the provision for adjustment both at the gudgeon-pin and crank-pin end by means of a strap. Lubrication provides no difficulty whatever, being effected by the drip from the oil cup above the engine at each down stroke of the piston, being splashed on each end of the connecting rod and the bulk falling into the trunk of the piston, where it is gradually used. A diagram of the oil feed and vaporiser is shown in Fig. 37, where it will be seen that the oil, after admission through a suction disc valve of special design, passes

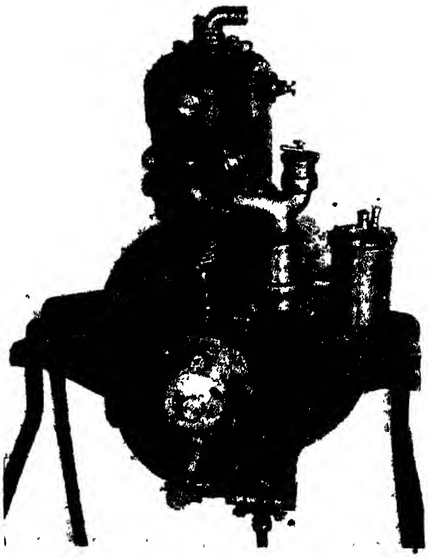


Fig. 35.—Parsons concentric valve engine.

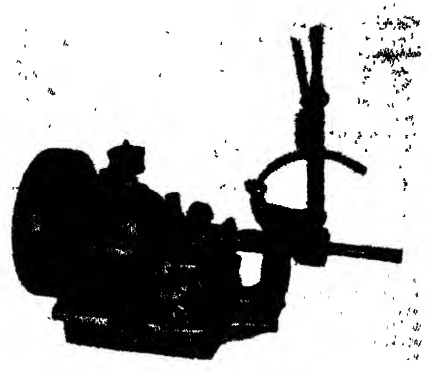


Fig. 36.—The Seal engine.

through a simple vaporiser to the chamber, where it awaits the opening of the automatic inlet valve. Once the oil feed is set by the regulator it requires no more attention, for the governing is performed on the exhaust by a

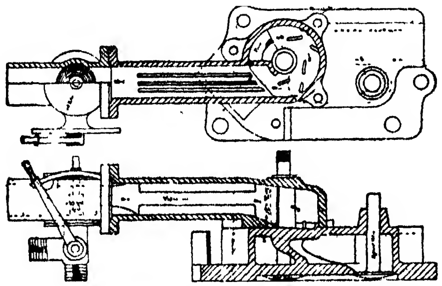


Fig. 37.—Seal vaporiser.

hit-and-miss device. The latest pattern of valve gear partakes of the familiar camshaft gear of the ordinary motor, the peculiar starwheel of the earlier Seal engine having given way to a pair of spur wheels, with a cam and lever for opening the exhaust valve. The governor, which is driven by a flexible wire belt, actuates a small centrifugal pawl in the large spur wheel, which throws the motion out of operation when the speed rises above a certain limit. Until the speed drops again below that limit the exhaust valve does not open, and, therefore, no new charge can be drawn into the cylinder. Ignition may be arranged either by a high-tension electric system, by automatic timed ignition, or by tube ignition. If petrol is used for starting the engine it is preferable to have the handy electric ignition, which obviates any delay for heating the tube. When, however, paraffin only is employed, the hot tube may just as well be used. In either case, after the engine has been running about five minutes, the automatic timed ignition takes up the firing, this being worked by a bulb, which, screwed into the combustion chamber, becomes incandescent and ignites the mixture at the correct moment determined by a mechanically-controlled plunger, which admits live mixture into the bulb. These useful little engines are made in three sizes, running at 750r.p.m.: single-cylinder 1½h.p. and 3h.p., and double-cylinder 6h.p., the details of all being the same. A commercial type is also manufactured.

An Example of Lamp Heating.

In this pattern is to be found an instance of lamp-heated vaporisers, the exhaust gases playing no part in the vaporisation system. In opposition to the usual practice of spraying the oil upon a hot plate, the Standard method is to spray the oil in contact with a current of superheated air, the heat being supplied by a burner in the base of the vaporiser. Air pressure maintains the feed of oil both to the vaporiser and to the burner contained within it, the quantity of oil admitted to form the working mixture being regulated by an eccentric controlled by the governor. In the motors of 20h.p. and less automatic vapour inlet valves are used, these being on the same side as the exhaust. The explosive charge drawn into the cylinder from the vaporiser is rich, and the proper mixture is obtained by dilution with pure air drawn in through an automatic inlet valve. In the 20h.p. model, illustrated in Fig. 38, one vaporiser feeds a pair of cylinders. Low-tension magneto furnishes the firing sparks, the tripping being controlled by the movement of the common operating shaft. On all sizes up to 20h.p. splash lubrication serves the working parts, but in the larger models this is supplemented by a positive pressure feed, a rotary pump drawing oil from a crankcase sump and distributing it under pressure to the main bearings, whence it flows through the hollow crankshaft and connecting rod to the crank and gudgeon pins, and from the latter to the cylinder walls. For ease in starting, relief-compression cams are fitted to the exhaust valve gear, a single lever forward sufficing to bring them into play. The governor is of the inertia or pendulum type, which is not

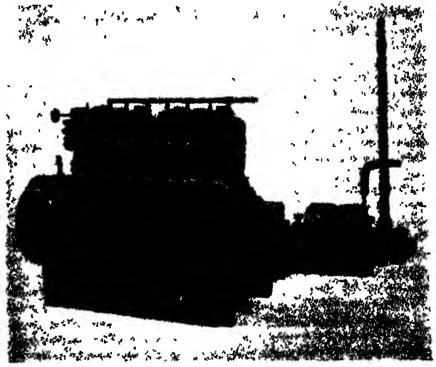


Fig. 38.—The Standard motor.

quite so sensitive as the centrifugal pattern, but it is simpler and more robust. Models of 5h.p., 10h.p., 15h.p., and 20h.p., developing their power at 800 revolutions per minute, are built up with one, two, three, and four cylinders respectively of the same bore.

The Thornycroft Vaporiser.

All the engines made by this firm are designed to run on either petrol or paraffin. For the consumption of the heavier fuel, a vaporiser of simple pattern replaces the float-feed carburetter, which is fitted when only petrol is to be used, but the vaporiser is so constructed that light spirit can satisfactorily be employed instead of paraffin whenever desired. The alterations made in the engines to suit them for the heavier fuel reduce the power about 15 per cent., as compared with the petrol models, nor will the full power of the latter be equalled even if the paraffin engines be run on petrol. For illustrating the Thornycroft motors in Class II., views have been employed which show the vaporiser fitted, because not only is it adapted to both fuels, but its employment entails no alteration in the accessory details of the engine. The best idea of the shape and construction of the vaporiser can be obtained from Fig. 23. It consists of an exhaust-heated box in which the paraffin and air are swirled intimately together. A float chamber feeds the fuel to a plain jet in the mixture inlet pipe. Just above the float chamber appears the main air inlet, through which the air is sucked to pass over the jet and carry paraffin away into the vaporiser, where a rich, vaporous mixture forms. After its treatment therein, it rises into a spherical chamber, where it is diluted by air from an auxiliary inlet just above, and is carried away to the cylinders. The main exhaust pipe passes through the base of the vaporiser, but the amount of hot gases admitted into the jacket is regulated by a valve controlled by a lever working on a quadrant on the exterior of the box. The heat can thus be regulated to suit the fuel, practically none being required for petrol. The auxiliary air inlet is interconnected with the throttle. A small door on the starboard side of the vaporiser permits a lamp to be used for warming up to start, if no petrol is available.

A Simple Conversion.

After long trials, the manufacturers have now perfected the vaporising arrangement by means of which the Wear petrol engines, described in Class II., are adapted for the heavier oil. The vaporiser consists of a simple exhaust-heated mixing chamber, provided with an extra air inlet. Only one vaporiser is employed for any of the engines in the three smaller series. Considerable alterations are made in the valve setting and combustion chamber, the ordinary petrol design being unsuited for burning paraffin.

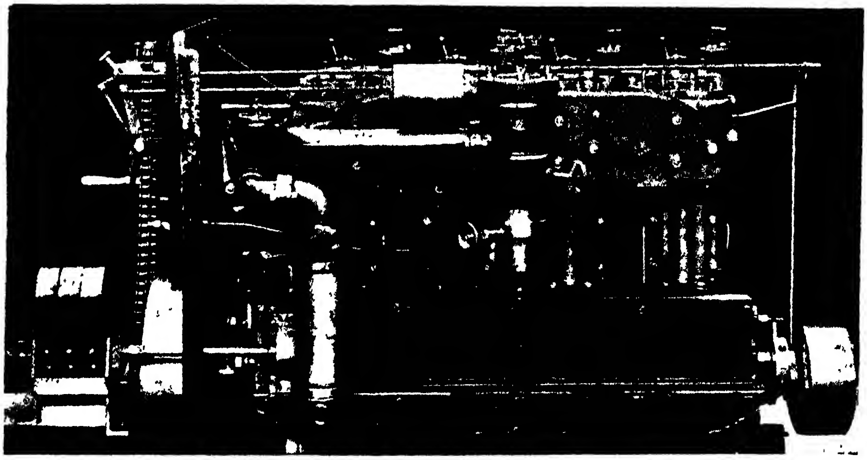


Fig. 39.—The Woodnutt engine.

An Elaborate Design.

Although a general impression of complication may be conveyed by a study of the four-cylinder 25-30h.p. engine illustrated in Fig. 39, there is in reality no ground for criticism on that score. It is to the unusual appearance of the valve-system covers and of the combined induction and exhaust box that the false impression is due. In the centre of the picture there is a Westmacott paraffin carburetter, heated by the exhaust gases brought to it through the short upper pipe on the left, and delivering its mixture directly into the induction passages that extend the full length of the engine. The longer pipe connected to the body of carburetter conducts

the exhaust back to the main pipe, which is water-jacketed as it passes down beneath the floor just behind the control board. Apart from this piping and from the corrugated covers fitted over the valve springs, tappets and guides, there is naught about the motor that would not appear quite commonplace at the first glance, albeit in the construction and design there are unusual features of a high degree of excellence. Thus the low-tension magneto ignition and half-compression device is so interconnected that when, in starting up, the compression is relieved, the ignition is thereby automatically retarded, and again, the gudgeon-pin bearings can be adjusted by long bolts at the side of the connecting rods and fitted to be accessible through the hand-holes of the crankcase. The cylinders are cast separately with all valves on one side, and have ingenious removable heads, that open up the full bore of the cylinders and permit the pistons to be drawn through. All joints are machined, no packing being required anywhere. In the design of the crankcase generous provision has been made for accessibility, there being a large inspection cover to each crank-throw on the starboard side, and two long panels extending the whole length on the port side. There is a bearing between each crank-throw. The long bolts that extend half the length of the connecting rod and permit the gudgeon pin to be adjusted through the inspection doors are unique. Between the valve tappets and the cams there are fingers, which carry rollers on their underside. This system overcomes all side thrust on the valve tappets. Another unusual feature is the fitment of centrifugal lubricators to the balanced crankshaft. These, which lubricate the crank pins, are fed from oil boxes fitted to the port side of the cylinders, from which also tubes are led to the main crankshaft bearings. Separate sight-feed lubricators supply the oil to the cylinder walls. Instead of the more usual centrifugal or rotary pump, a plunger pump is fitted for the water circulation, and is driven off an extension off the camshaft. Control is effected by the throttle of the carburetter, which is connected both to a hand lever on the control board and to a centrifugal governor on the forward end of the crankshaft. Two most commendable features remain to be mentioned: one, the provision of the chain starting gear behind the control board, and the other the placing of the magneto in the same position. As the power of these engines increases, so is the speed reduced, the range being from 550 revolutions per minute to 700 revolutions per minute.

Class V.

The following paraffin medium-speed engines (single and multi-cylinder), of both two-stroke and four-stroke cycles, are dealt with:—

Brit.	Parsons.
Gardner.	Pasley.
Macdonald.	Seal.
Marmot.	Thornycroft.
Mitcham.	Wear.

Brit.

In the West Country especially the 6h.p. Brit motor has been giving very good results for some time, but it is also becoming known further afield. It has been specially designed for the heavier fuel with its own particular vaporiser. Running only at 600 revolutions per minute, it is specially suitable for heavy work. Both valves are situated on the after-end of the cylinder, this position has been chosen for the vaporiser, through the jacket of which the whole volume of exhaust gas is discharged. Thus fitted, the vaporiser occupies no extra space beyond that required in any case for the engine. The paraffin enters through a small port in the seating of the automatic air-inlet valve of the vaporiser, the correct quantity being adjusted by a needle valve. Only a rich mixture is formed in the vaporiser chamber, and it is not until this has mixed with the cold air drawn directly into the cylinder through another automatic air valve that the correct proportions of combustible gas are obtained. For starting up the engines a blow-lamp must be used, but thereafter the exhaust gases provide the necessary heat to the vaporiser. Low-tension magneto ignition is fitted, the ignition being arranged to spark in the inlet valve pocket, for it must be noted that although mention is made of two automatic air valves above, one in the vaporiser and one in the cylinder head, it is a mechanically-operated valve that admits the mixture from the vaporiser into the cylinder. Lubricating oil is supplied directly to the principal moving parts from a mechanical lubricator driven off the main shaft. The rotary water pump and magneto are both driven off a lay shaft, the gearing for same, although covered, not being entirely enclosed. Multi-cylinder engines up to 24h.p. are constructed with the same size cylinders, a vaporiser being fitted to each cylinder just as in the case of the single-cylinder engine.

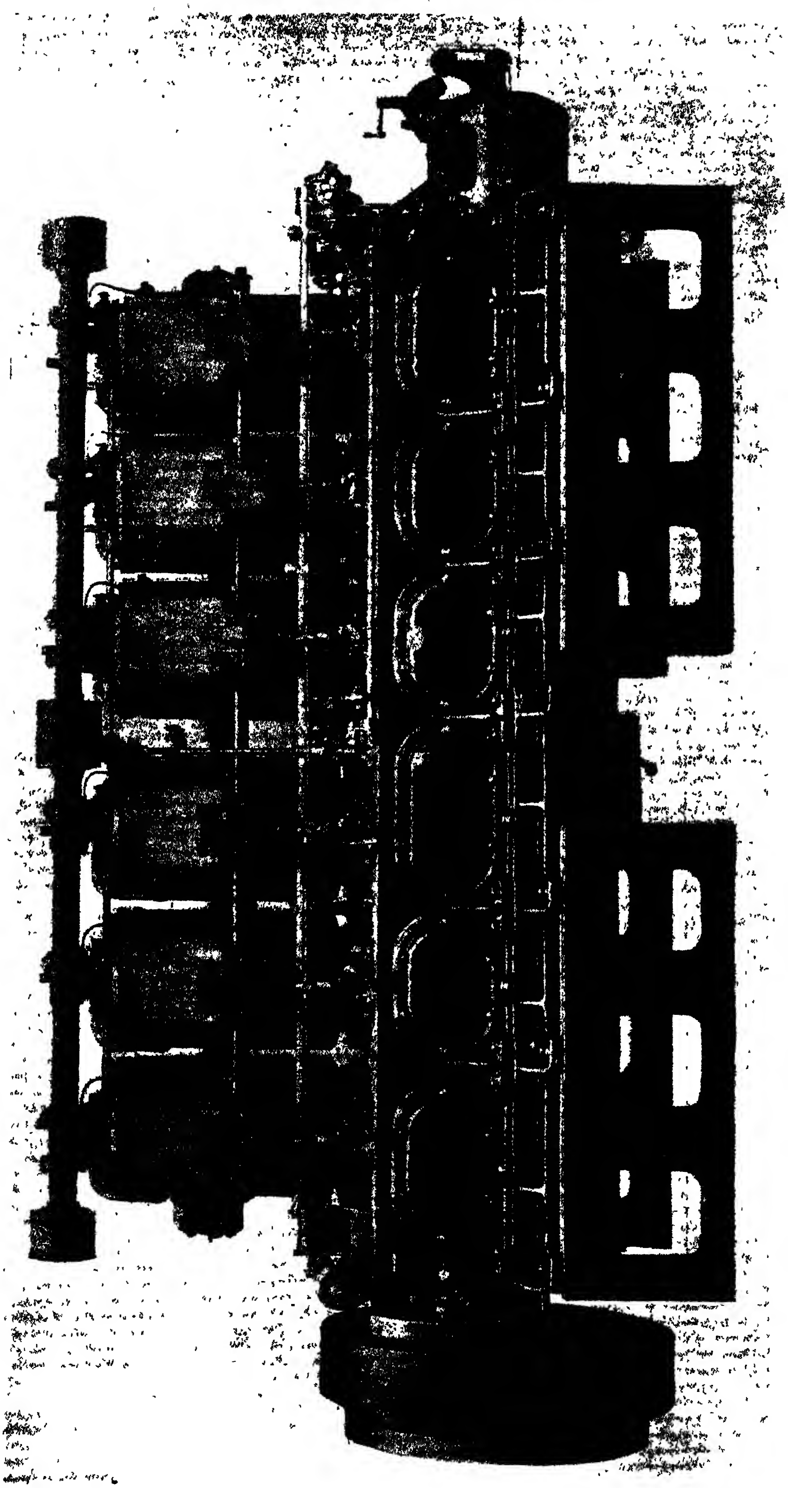


Fig. 40.—A 200h.p. Gardner engine installed in the auxiliary motor yacht "Modwena," one of the largest, possibly the largest, of her type in the world.

A 200h.p. Engine.

A full description of the leading features of Gardner engines is given in Class IV. It remains only to be mentioned here that a large range is provided of models running at a medium speed. There is a series of two, three, and four-cylinder engines, developing 11h.p. per cylinder at 600 revolutions per minute, and types of two, three, four, and six-cylinder sets giving 18h.p. and 33h.p. respectively, the former at 500 revolutions per minute and the latter at 450 revolutions per minute. It is the biggest of the latter, a 200h.p. six-cylinder, that is illustrated in Fig. 40. This engine is installed in the auxiliary yacht "Modwena."

A Simple Model.

Being of simple and robust construction, the Macdonald engines are specially suitable for rough, heavy work. The cylinders are cast separately, with the vaporisers forming integral portions of each. When the engine is cold, a blow-lamp must be used for warming up, but provision can be made for starting on petrol. The vaporiser consists of an exhaust jacketed mixing chamber, to which the paraffin is admitted through a needle valve to mix with the air, and pass thence through an automatic valve into the combustion chamber. The paraffin feed is regulated by the governor fitted to the main shaft. For ignition the Lodge patent high-tension system is employed, this rendering the sparks absolutely sure, even if water fall on the circuit or the plugs become sooted. Splash lubrication serves the smaller models up to 8h.p., but the larger engines are fitted with a forced system. The water circulation is maintained by a rotary pump. Large inspection doors are fitted to the crankcase, and beyond the balancing of the crankshaft there is no other detail to be mentioned, so simple is the design. The single-cylinder engines of 2h.p., 4h.p., and 6h.p. turn at 700 revolutions per minute; the two-cylinder models of 8h.p., 10h.p., 12h.p., and 15h.p. are designed to run at 600r.p.m., except the latter, which is made for 500r.p.m.; and the larger three-cylinder types, varying from 20h.p. to 50h.p., run severally at 500r.p.m., 400r.p.m., and 350 revolutions per minute.

An All-paraffin Engine.

Being among only the very few two-stroke engines on the British market designed to burn nothing but paraffin fuel, the Marmot possesses a special interest. The vaporiser shown on top of the cylinder in Fig. 41 is heated in the first instance by a lamp of special design, in which the oil is burnt under air pressure after the method employed in liquid fuel burners for boilers. The lamp itself requires no preliminary heating, the burner lighting instantly like a gas jet. When the engine has been started, the burner is extinguished and the igniter bulb, or vaporiser, as it is commonly termed, although it does not perform any vaporising function in this engine maintains its heat from the constant compression and successive explosions in the cylinder. It is as the piston travels upwards and the inlet and exhaust ports have been closed in succession that the oil is sprayed into the cylinder by means of a pump, where it is at once vaporised and compressed into the igniter chamber on the cylinder head, which is not water-cooled. The charge fires automatically just as the piston reaches the top of the stroke. The two-stroke cycle being employed, there is a power-stroke on each revolution. The crankcase acts as the air-compression chamber, and though long bearings are fitted to obviate leakage as far as possible, should leakage occur, there is no loss of fuel. Inspection doors are fitted on each side. Except in the single-cylinder models, where spur gearing is used for the purpose, the oil-feed pumps are driven through a chain, each plunger being operated by a cam. Each cylinder has its own pump, which delivers into the combustion space just below the igniter bulb. A centrifugal governor regulates the quantity of each charge of fuel according to the load. Although in the smaller sizes the cylinder head is not cooled, a jacket is fitted to the cover in the larger sizes. A plunger pump maintains the water circulation, and when water is discharged into the exhaust pipe the pump is made double-acting to draw off any surplus water from the exhaust box or silencer. A branch from the water-circulation system is taken to a nozzle in the cylinder wall, which, being uncovered at the same time as the exhaust port, sprays a little water into the cylinder to deaden the sound of the exhaust and facilitate the scavenging of the waste gases. Lubrication of the main bearings is carried out by spring grease cups, but sight-feed oil-drip cups are provided for the cylinder and crank pin, the latter having a ring lubricator. The range

Fig. 41.—The Marmot motor.

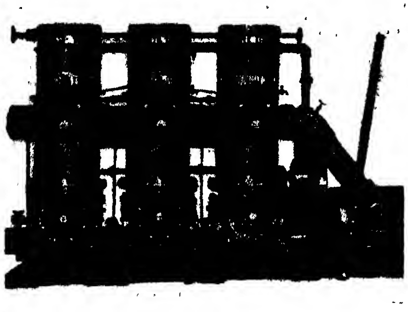


Fig. 42.—The Mitcham engine.

of models is from 5h.p. to 30h.p. in one, two, or three-cylinder units, all running at the moderate speed of 500 revolutions per minute. Engines of more than 15h.p. are fitted with a compressed air starting arrangement, by means of which air is admitted to the top of the pistons. A hollow-ported elongation of the compressor piston regulates the admission of air, the timing being obtained by the adjustment of the eccentric, which drives the compressor directly off the crankshaft. The compressor charges an air tank, from which air is drawn for working the heating burners as well as for starting up the engine. A hand air pump is supplied for charging the air reservoir, should the latter become exhausted. It will be noticed from the illustration that a bracket is provided for the heating lamp, the burner of which blazes directly on the cover of the igniter bulb, and that a lid is fitted to cover the burner orifice when the lamp is extinguished. As an example of a simple, commercial engine, the Marmot is particularly good, and beyond the Border it is making a good name for itself.

The Mitcham Engine.

By a special disposition for the vaporisation of the heavy fuel and a slightly different cylinder, all the Mitcham two-stroke motors referred to in Class III. can be adapted to burn paraffin fuel. Further, a special series of two, three, and four-cylinder engines of 30h.p., 45h.p., and 60h.p., all running at 400 revolutions per minute, has been designed for commercial work. In the accompanying illustration (Fig. 42) the general lines of the type can be seen. Petrol is used for starting, and until the engine is warmed up, the details of the formation of the mixture being exactly as described for the petrol engines of this make in Class III. For the vaporisation of the heavy oil, a special jacket is placed round the exhaust jacket, and into the chamber so formed a measured quantity of oil is dropped, where, falling on the heated surface, it is vaporised. Pure air only is drawn into the crank chamber and compressed there. When the inlet port is opened, the air under compression is forced round the jacket, where it mixes with the paraffin vapour and passes thence into the combustion chamber. Low-tension electric ignition is employed. If desired, the engine can be started by heating up the exhaust-jacket chamber for 10 or 15 minutes, and then cranking up in the usual manner.

A Large Motor.

A three-cylinder 75h.p. and a four-cylinder 100h.p. model are now made by the Parsons firm, with their patent valve combination as described in Class IV. Both these large types develop their rated power at 450 revolutions per minute. Owing to the convenience of being able to start on petrol and to change over to paraffin after a short period, this type of engine is particularly suited for installation as auxiliary power.

A Low-speed Engine.

Although the firm has been making marine motors for 10 years past, the trade having been chiefly abroad, the Pasley engines are not so well known in the United Kingdom as would be expected. They are of simple design, but possess several features that deserve mention. The cylinders are fitted with liners, and, therefore, of course, have detachable heads. They are bolted to a stout crankcase, fitted with large inspection doors on both sides, through which both ends of the connecting rod can be adjusted, the bolts being designed for the purpose. For starting, the ignition is effected by a hot tube, heated externally by a protected blow-lamp, but after the engine has run for a few minutes the flame may be extinguished, the internal igniter coming into operation and functioning automatically.

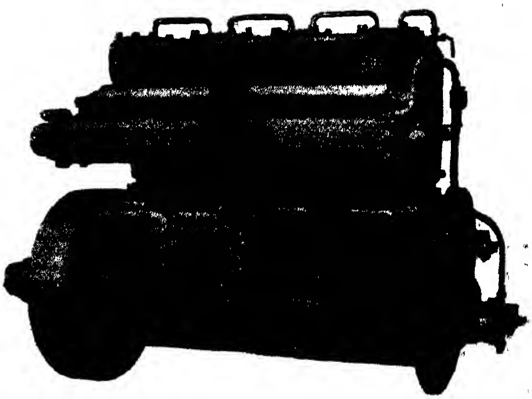


Fig. 43.—A Parsons 100h.p. engine, 9in. bore by 12in. stroke.

Fig 44.—The Seal heavy type.

The vaporiser is a simple exhaust-heated chamber, to which oil is fed by a spray. Initially, this must be heated by a blow-lamp. The speed is regulated by the throttle, which is under hand control and can be regulated also by a governor if desired. The valves, being side by side in the cylinder head, are actuated by long push-rods and rockers, the camshaft being contained in a case alongside the crank chamber, the gearing being completely enclosed. Splash lubrication is used for the main bearings and connecting rod ends in the smaller engines, with sight-feed drip to the pistons, but in the larger models the oil is fed directly on the bearings by adjustable drips. One, two, and four-cylinder engines are built from cylinders of different sizes, developing respectively 7½h.p. at 600 revolutions per minute, 10½h.p. at 550 revolutions per minute, 15h.p. and 18h.p. at 500 revolutions per minute, and 25h.p. at 425 revolutions per minute, the four-cylinder 100h.p. engine built from the latter cylinders being supplied with an auxiliary engine for starting.

A New Heavy Type.

A sound type of commercial engine has recently been introduced by the Seal Company. It is designed and built on the same lines as the Seal motors described in Class IV., but the valve mechanism is different (see Fig. 44), and its engine speed is only 450 revolutions per minute. Two sizes are made: a 7h.p. single-cylinder and a 15h.p. double-cylinder, both with a bore of 7½in. and a stroke of 6in. The former weighs 5cwt. and the latter 8cwt. The type is intended purely for commercial work, and so differs in detail from the other Seal model.

A 300h.p. Submarine Engine.

Up to the present only one larger marine motor has been constructed in this country than the eight-cylinder Thornycroft engine, developing with paraffin fuel 300h.p. at 600 revolutions per minute. This type is in use in Italian submarines. A general idea of the design can be grasped from the port view in Fig. 45. It can be seen that the engine is really built up from two four-cylinder units, each of which is complete in itself and can be run separately if desired, although, the coupling between them being fixed, one unit must run idle if the other alone is working. The principal reason for this method of construction is, however, to be found in the advantages it offers for reversing. Accessibility being of paramount importance for submarine work, the crankcase doors have been made large enough to enable the piston and connecting rods to be withdrawn without disturbing the cylinders. The inlet and exhaust valves are all arranged in the cylinder head, being driven by a single camshaft in a case running alongside. All the piping is brought to one side, the induction system being taken over the heads and the exhaust straight out through the side. Short rocking levers transmit the motion from the cams to the valve-stems. Although, as usual in overhead valve systems, the inlet valves are fitted in cages, the exhaust valves are not so treated because of the difficulty that would occur in properly cooling the seats. They are therefore placed in position from inside the combustion space, access being obtained through the inlet valve passage after removal of the valve cage, the latter being a simple operation owing to the bayonet-joint fitting. The exhaust valves thus rest on properly-cooled seats in the combustion head, and are not liable to overheating. Each pair of rocking levers is secured by three nuts, any work to be done on the valves of a particular cylinder therefore being possible without disturbance of the valve gear of the other cylinders. Each four-cylinder unit has its own camshaft drive, the vertical shaft by which this is transmitted being skew-geared from the crankshaft and bevel-geared at the top. Both shafts are situated at the after end of the respective units, with the gearing entirely enclosed. For the engine reversing, in which case the direction of rotation of the camshaft must be changed, an exceedingly simple contrivance has been adopted. In the bevel case at the top of each vertical shaft the driving pinion meshes constantly with two opposed bevel wheels on the camshaft, either of which is engaged by a small dog clutch. In reversing, the controlling lever is thrown over just before the engine comes to rest, a spring-loaded coupling being inserted in the reversing rod for this purpose, because the teeth of the clutch thus engage more easily. Compressed air is employed for starting the engine astern after it has come to rest, and, of course, because the half-time bevel-gearing has also been reversed the camshaft will run in the same direction as when the engine is driving ahead. The cams are therefore only single-faced. For the compressed air starting separate valves are fitted under the camshaft casing on the port side. These valves are operated by rockers off the camshaft, but in order that they

may be thrown out of action when the engine is working the valve tappets are constructed in such a manner that they can be rendered inoperative in an instant. For this purpose they are fitted each with a pinion, engaging with a rack extending the full length of the engine. By a short movement of the rack, the pinions, in turning, adjust the tappets either to work the valves or to remain idle. Parts of this gear, with the compressed-air supply pipe, can be seen in Fig. 45. A simple form of vaporiser is attached to each four-cylinder unit. It lies transversely across the after end of each engine, and is jacketed by the exhaust. Paraffin is sprayed into it from a large jet to meet the small quantity of incoming air admitted to the vaporiser vaporiser jacket. Low-tension magneto ignition is fitted, the igniters being inserted in the cylinder walls next the starting valves. They are ingeniously made, the striker being tripped by a rotating finger mounted on the spindle of a skew-geared pinion, with its axis at right angles to that of the camshaft in the vertical plane. To vary the timing it is only necessary to slide the driving pinion along the camshaft, for the skew-teeth must advance or lag in relation to each other as the driving contact is shifted. The magnetos are bolted to brackets on the end cylinders, where they can be driven by short skew-geared spindles off the camshaft. Special means for localising a faulty igniter are fitted, this being rather an unusual device for low-tension

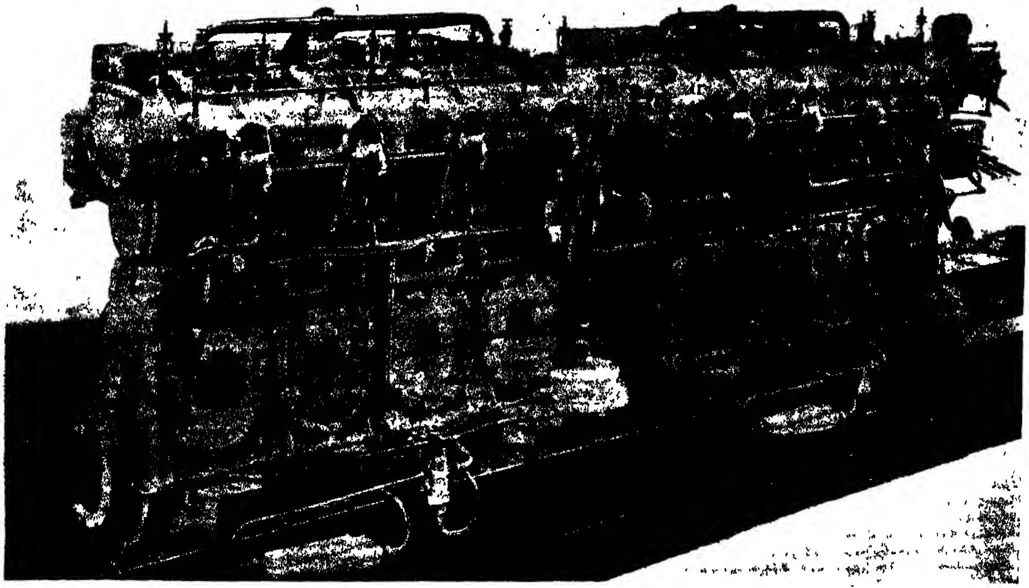


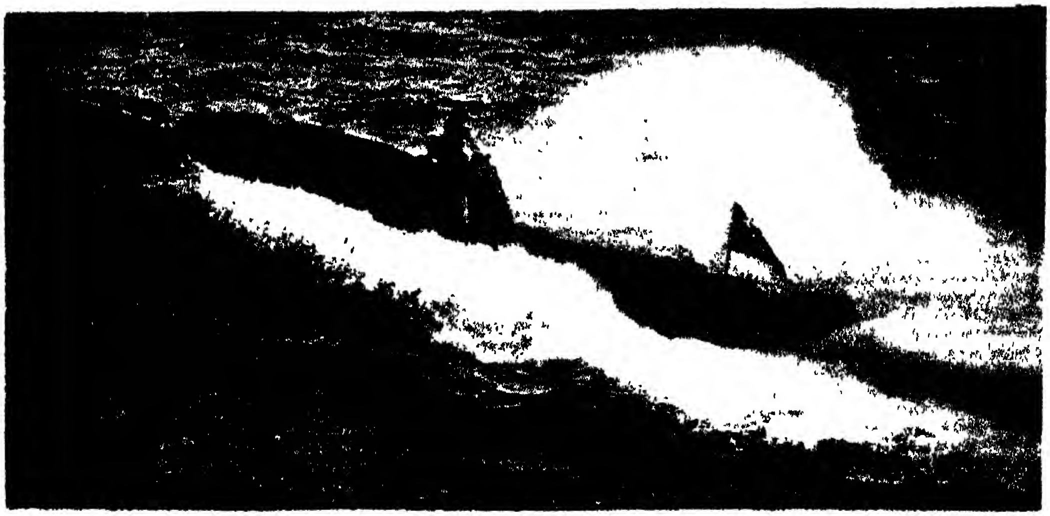
Fig. 45.—A 300h.p. Thornycroft submarine engine.

chamber. Mixing intimately during their path through the heated chamber, they form a mixture that is diluted by a regulated quantity of air before the throttle is reached and then passes through a nicely-balanced system of piping into the cylinders. A valve controls the flow of exhaust gases round the vaporiser in order that the heat may be regulated for different qualities of fuel. Water-drips are arranged over each inlet valve to admit water with the mixture into the cylinder for the purpose of deadening the thump of the explosion. The exhaust system is entirely water-cooled with the exception of the systems. Forced lubrication is of course adopted for the moving parts in the crank chamber, the oil being fed under pressure to the main bearings by separate pipes, then through the hollow crankshaft to the crank pins and up through the connecting rods to the gudgeon pins. The pressure can be regulated, and a gauge is fitted to indicate it. The camshaft and valve rocking levers are lubricated by sight-feed drips. For the purpose of being able to rapidly cool the engine after it has ceased running, the water-pumps are independently driven by electricity. The path of the water is

unique, lying first through the false bottom of the crankcase, in order to cool the oil, then up the hollow webs that support the main bearings, which are thus guarded from overheating, and by means of a pipe from each web to the cylinders, after passing round which it is discharged through the jackets of the exhaust system. An electric fan sucks the hot, exhaust-tainted air from the crankcase and drives it out through a ventilating shaft. Pure air is admitted to replace it through gauze-protected holes in the crankcase doors. With reference to the adoption of the coupled four-cylinder units, it should be explained that the reversing system requires the cranks to be spaced 180° apart, which is exactly as they occur in four-cylinder engines. In a good many types of eight-cylinder engines the cranks are set at 90°, which is unsuitable for the simple reversing arrangements adopted in this engine. Moreover, the four-cylinder units being coupled at 90°, are equally well-maintained torque is provided. Between the two crank chambers of each engine a stoutly-flanged casting is bolted for rigidity, and not only are the cylinders also rigidly coupled by a longitudinal stay on each side, but the camshaft case is also supported by rods from each cylinder, all of which makes for extreme rigidity. All the control levers are mounted at the rear end of the engine. They are four in number, and operate the interconnected throttles, interconnected ignition timing, interconnected reversing rods, and the compressed-air starting valves. The control gear of the exhaust gases round the vaporiser jacket is mounted separately lower down, but the extra-air admission valves are adjusted by levers on their respective engines. The consumption of paraffin is just over .7 pint per horse-power hour; of lubricating oil about .03 pint per horse-power hour; and of injected water about .11 pint per horse-power hour. In Class II. further reference is made to this engine.

Wear.

In the series of heavy-duty engines, developing 16h.p. per cylinder at 400 revs. per minute, the Wear vaporiser, described in Class IV., is fitted to each pair of cylinders, and the valves in this type being on opposite sides, the exhaust pipes are brought through between each pair of cylinders directly to the vaporisers before joining the main exhaust pipe.



Section 11.—Commercial Motors.

Although in the strict sense of the word any motor might be termed "commercial" when it is employed in a boat or vessel used for business purposes it has become arbitrarily recognised that the term should be appropriated to a class of heavy, slow-running, paraffin engines which are particularly suited for commercial craft. Even within these limitations it is not possible to designate a particular type, for the eight-cylinder 300h.p. Thornycroft engine can be quite as usefully applied to business interests in its own sphere as the 4h.p. Dan, and the entire range of Gardner motors give practical advantages that in most instances permit them to be no more separated from the commercial category than the Kromhout or the Van Rennes.

Under the circumstances, it has been deemed best for the general utility of this treatise on engines to classify the paraffin commercial engines even more strictly than is generally considered necessary. In one category can be placed the Dan, Kromhout, Van Rennes and Thornycroft suction-gas engines, etc., and in the other will fall such motors as the Gardner and Thornycroft paraffin engines of large size and power and running at a moderate speed, which can be deemed neither high nor low. So many different requirements can arise that it is not easy to define the useful spheres of each, nor can a hard-and-fast line be drawn as a boundary between the rational uses of the two.

In a broad and general sense the heavy, slow-running, commercial engine may be considered as the correct type for all boats and vessels which possess a very small ratio of power to displacement. Barges such as one finds on the Dutch canals, heavier types of fishing vessels such as Norway and Denmark can boast of, coasters and traders such as exist in every quarter of the globe—these are the craft for which the heavy, slow-running engine can be deemed especially suitable. For with their slow speed, their low power, and their big displacement a large propeller is a necessity if efficient results are to be obtained. A smaller propeller running at a higher number of revolutions cannot work at the same efficiency. Amongst naval architects no doubt whatever exists on this score, for if practice had not proved it to be right, it could easily be deduced by theory.

The moderate-speed, big, paraffin engines can be employed for the same purposes, but they can neither give the same speed for the same power nor at the same price. Their sphere lies properly in faster and smaller-bodied vessels, where the water can easily get to the smaller propellers, and which permit an efficient pitch angle on the screw. The Gardner engines have shown themselves remarkably suited to fast-service boats, and the Thornycroft paraffin motors have demonstrated their utility in the same direction. The extremely heavy, slow-running engines could not be so serviceably employed under the same circumstances. Thus the extreme spheres of usefulness of the two types can be readily delineated, but it is not possible to define the boundary between them, nor even how far, in justice to themselves, they may be allowed to overlap. This must remain a matter for individual choice in each case, depending upon a variety of circumstances. That the distinction can, however, be drawn is not to be overlooked. It is, in fact, important, because so long as the generic term "commercial engines" is employed without regard to weight and engine speed, so long will it be possible for the enterprising spirits to whom we must look for the advancement of the cause in this country to be led to disappointment by a misunderstanding of the actual influence of the reigning conditions upon the efficiency of the installation and upon the success of their undertaking from the economic point of view.

In many instances the commercial engine is destined to be entrusted to the care of one who possesses not even an elementary knowledge of mechanics. For this reason it has always been urged that simplicity in design and construction is one of the greatest virtues that an engine of this type can possess. To insist too much upon this attribute is, however, to rule electric ignition, amongst other things, out of court. Unless one can open one's eyes to a broad vision of the commercial marine motor world, not alone as it is to-day, but as it has been for a decade past in foreign countries, one would be apt to judge that electric ignition certainly is a detail that should be missing from the commercial engine. Let it not, however, be overlooked that in Holland, where barge owners, almost to a man, have adopted oil-engine power, automatic ignition is by no means alone in favour. Neither in the Kromhout, nor in the Van Rennes, nor in the Deutz, which shares with the two former a majority of patronage of the Dutch and German barge owners (many a Rhenish barge is wrongly accounted Dutch, when it is really German), is the automatic hot-pot

vaporiser to be found. It therefore behoves one to be circumspect in discussing the relative merits of the two systems, for surely if the Dutch prefer electric ignition and the Danish and Norwegian incline to the automatic, there can be little to choose between the two. And as it is with this detail, so is it with others. Simplicity, if hunted to death, loses its virtue and becomes a vice. In the types treated in the following pages it will be found that the desirable attributes of the commercial engine are to be discovered in varying degrees, but all are simple, all are robust, all can run for long periods without skilled attention, all can be started easily, and there is not one that cannot boast of a splendid record and reputation in its own country. Suction gas, it is true, has yet to make its mark, but it is beyond the experimental stage. With these remarks the descriptions in the following pages will appear to readers in a different light to that which is due merely to the words.

Class V.

Paraffin medium-speed engines of all types - Identical with Class V. in Section I. for Private Craft.

Class VI.

The following paraffin slow-speed engines are dealt with:—

Dan.
Griffin.
Kromhout.
Pasley.
Van Rennes.

The Dan.

In the Dan engine, which came to this country more than three years ago with a great reputation from Denmark, every effort has been made to reduce the design to its simplest expression. For nearly ten years it found an ever-widening sphere of utility in its own country before Capt. Cumming, R.N., selected it as the most suitable type for demonstration purposes in the Scottish Government's auxiliary fishing boat "Pioneer," and since a well-known firm of naval architects has obtained control of the British selling rights it has met with considerable success in home waters. In fact, so suitable has it proved for unskilled handling in various types of vessels throughout the world, and so well has it been received in this country, that arrangements have now been completed for its construction by a well-known firm of engineers on the East Coast. Not a bolt nor a nut has been altered in the British type, which is an exact replica of the current model built in Denmark. It was, indeed, felt that experience has shown the design to be perfectly suited to its work, and that no practical improvement could be made. But for the fact that the general demand is for a British engine, there would have been no inducement to the concessionnaires to have it made in this country, for the Danish factory long ago demonstrated the excellent quality of its material and workmanship, without which in truth no commercial engine could be a success.

It is, of course, in the vaporising system that the secret of economy and reliability is to be found. The cylinders have water-cooled bodies, but unjacketed heads, for the vaporiser, which must be maintained at a good red heat, is attached to the head. Its shape is like that of a glass jampot, but with a somewhat narrower and longer neck, inverted on the cylinder cover. Into the wall of the vaporiser passes the fuel inlet pipe, which is water-cooled at this spot. The paraffin is pumped up a tube to the inlet pipe, the delivery being made at the top of the exhaust stroke, and, owing to the water cooling on the inlet, the paraffin always passes into the bottle vaporiser at an even temperature. Being, moreover, sprayed through a nozzle (see Fig. 46), and entering at a time when the remains of the last burnt charge are in a state of commotion, the paraffin is immediately vaporised, there being no cracking of the oil. In some oil engines the charge is injected during the compression stroke, in others during the suction stroke, but the Dan system has shown itself to provide as much power and economy as any other methods. For starting up at any time recourse must be had to a Swedish lamp, in order to give the vaporiser its initial heat,

but when this glows red the engine will start away easily. The lamp may then be withdrawn, for on each explosion there is an accession of heat to the vaporiser, which ensures its maintenance at an even temperature.

Just forward of the clutch is a centrifugal governor, mounted on a worm-driven shaft running at half the speed of the engine. Off the same shaft are driven the plunger paraffin pumps, one to each cylinder. The governor, by altering the length of the stroke of the plungers as the load on the engine alters, and the speed rises or falls, effectively varies the strength of the fuel charge and automatically controls the engine. A hand adjustment is provided for setting the governor to work at any desired speed. In this manner one obtains the simplest possible control. There is no mechanical ignition apparatus, and, with the exception of the lubrication, there is no detail other than the adjustment of the governor to which any attention need be paid. On each cycle, of course, the charge is ignited by the heat of the vaporiser when the mixture of air and paraffin vapour has reached a proper compression. And it is by the constant recurrence of the explosions that this automatic ignition is rendered so thorough. Hence the reason for governing by the variation of the fuel charge instead of by the "hit-and-miss" system, so often adopted for heavy oil engines.

In the smaller sizes the automatic air-inlet valve is situated right over the exhaust valve in a water-cooled chest on the cylinder; in the larger sizes the inlet valve is mechanically operated by the side of the exhaust valves. The water cooling of the valves is very thorough,

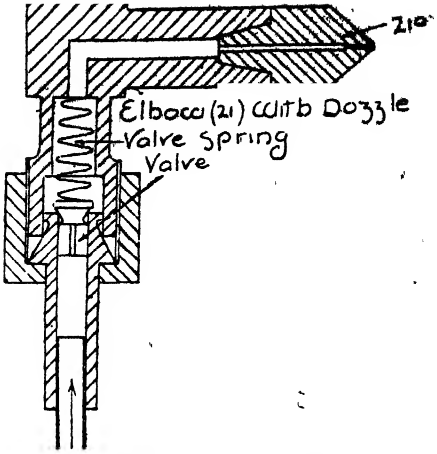


Fig. 46. -The Dan fuel feed.

and the half-speed shaft is provided with double cams for relieving the compression when starting up. A water-circulating pump and a bilge pump are also driven by this shaft. After passing round the cylinders and valves—with a branch to the fuel inlet on each vaporiser—the circulating water is led to the exhaust ports that form a standard detail of all Dan engines.

Lubrication is effected by a separate feed to each bearing. On the port side of the engine one or more oil boxes, situated at a convenient height, ensure the regular distribution of the oil by a number of wicks, one to each pipe.

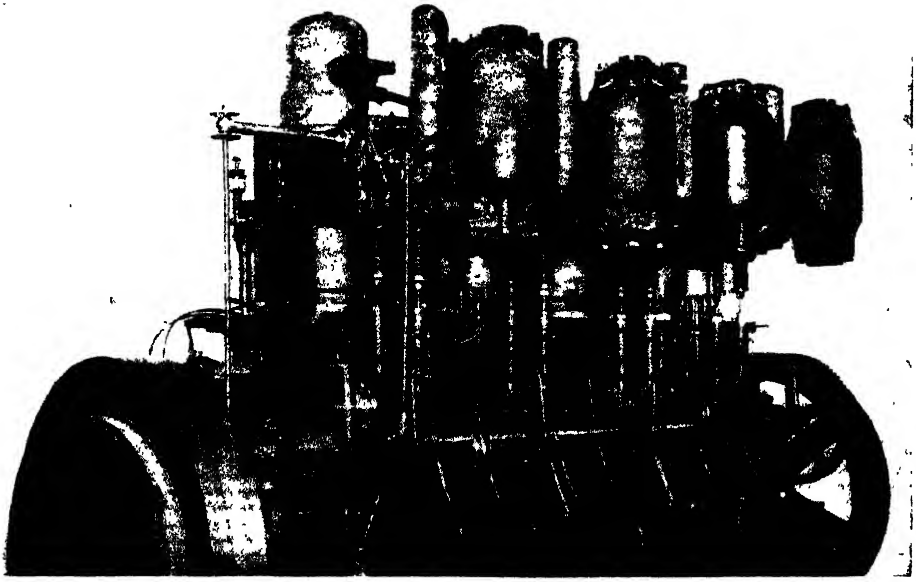


Fig. 47.—A four-cylinder 60h.p. Dan motor.

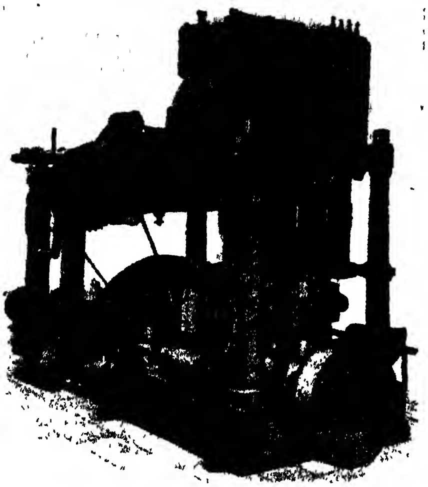


Fig. 48.—Cylinder arrangement of the Griffin motor.

At any time the supply can be easily and quickly replenished. Of the other details of the Dan design it need only be mentioned that durability, simplicity and accessibility have been carefully studied throughout. Lack of space prevents a more complete description, but notice must be given to the hoods that protect the vaporisers from external variations in cooling. These engines are made in single-cylinders from 3h.p. to 10h.p., in two-cylinders from 12h.p. to 30h.p., and with four cylinders of 60h.p., the latter being represented in Fig. 47.

An Unusual Type.

Presenting many features of extraordinary divergence from general practice, and because it has constantly proved capable of running on any oil fuel of less than 250° F. flash point, the Griffin engine might almost be reckoned in a class by itself. It would seem necessary to emphasise that it works on the four-cycle principle, for its unusual construction might lead to the impression that it works on a cycle as distinctive as that of the Diesel. One of its most important characteristics is the combination of cylinders side by side, which saves both space and weight by the reduction of mechanism. Two illustrations of the type are given in Figs. 48 and 49, the first representing the duplex design adopted for all powers between 20h.p. and 40h.p., the second being the quadruplex pattern for powers between 80h.p. and 150h.p. Smaller, larger, and intermediate sizes are built, but the illustrations represent only the models specified. In Fig. 48 the arrangement of the two vertical cylinders can be clearly noted. At their outer ends the pistons are connected to a rigid, crucible-steel crosshead, which, by means of a single connecting rod, actuates a single crank, which thus obtains an impulse on every revolution. The vaporiser and valve gear is fitted to the rear end of the cylinders, the camshaft being transversely placed. No crankcase is employed, the cylinders being held by four stout columns. Splash panels are easily attached, but the oil being led to each bearing by a separate drip-fed pipe, there is little oil cast about. The method of forming the working charge is novel. Into the centre of the vaporiser (see Fig. 50) oil is injected in a finely-pulverised state by means of an air jet working at a pressure of about 16lb. per square inch. The surrounding chamber is the heating jacket through which the exhaust gases pass, and the outer passage, which is open to the atmosphere, heats the inpassing air on its way to the central vaporising chamber, where it mixes with the vaporised oil to form the explosive mixture. The process that occurs in the vaporiser amounts really to fractional distillation. If refined oil be used, the whole of the constituents will be vaporised, whilst, if crude oil be employed, the heavy asphaltum base is rejected by the lighter constituents which are vaporised, and, being thrown down in the vaporiser, is automatically discharged, flowing off continuously in the form of liquid tar. Nothing ever remains in the chamber except a little incombustible ash, which can be removed by means of a wire brush every two or three days. The temperature of the vaporiser being regulated and controlled, there is always sufficient heat, even at the lightest loads, to vaporise the heaviest oils, whilst, on the other hand, it is never sufficient to crack or gasify the oil, the change being purely physical and not chemical. There is an entire absence

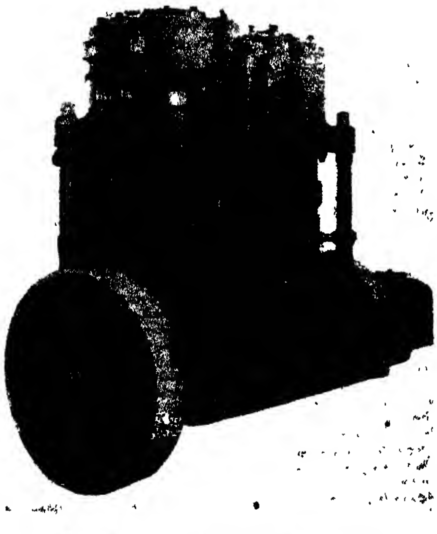


Fig. 49.—"Quadruplex" Griffin motor.

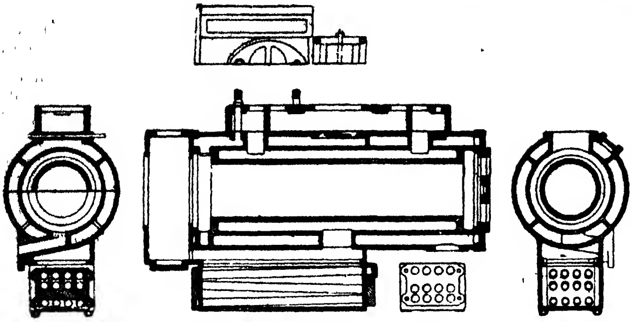


Fig. 50.—The Griffin vaporiser.

other type of magneto belongs to the rotary class, but it is unique in being designed to have a greatly-accelerated angular velocity at the periods of sparking. Whilst running at the average speed of the motor it obtains its acceleration at the proper moment by means of the train of oval wheels through which it is driven. The teeth of these wheels are prime to each other. The major and minor axes are, for practical purposes, in the ratio of about two to one, and arranged either in simple or compound proportion, as may be required, the major and minor axes

of tar in the valve chambers and cylinders, the vaporiser rejecting it entirely. During the process of vaporisation it is only the oils with a flash point of not more than about 200° F. which are taken into the cylinder in the form of refined vapour, and if, as it leaves the vaporiser, it is passed through a still, it will condense into pure petroleum, the exact quantity vaporised being thus recovered, although it will not correspond to the weight of crude oil used, because of the tar thrown down in the vaporiser amounting to about 10 per cent. of the whole. The heavy, tarry deposit has a full commercial value, and may be employed for all purposes to which ordinary coal tar is applied. The combustion is so thorough that, even at the lightest loads and using crude oil, the exhaust is practically clean. In all the engines of more than 20h.p. an arrangement of steam generator and superheater, combined with the vaporiser, is employed, in connection with an automatic steam valve operated by the governor, to furnish a suitable proportion of super-heated steam to the cylinder in intimate mixture with the heavy carbon charge. The heavy, detonating shock so often evident in the working of large oil engines is thereby entirely eliminated, owing to the reduced rate of combustion. Further, the decomposition and utilisation of the constituent gases, oxygen and hydrogen, increase the thermal efficiency of the engine. In Fig. 50 this superheater may be discerned under the vaporiser. It consists merely of water and steam tubes subjected to the 400° F. temperature of the exhaust gases. Automatic tube ignition is fitted to these engines ordinarily. It consists of incandescent tubes, heated by jet spray burners, which can be regulated to maintain the tubes at their proper cherry-red heat. Low-tension electric ignition can be fitted, either as an auxiliary or as the sole system. There is a choice of two machines, both manufactured at the Griffin factory. One is of the oscillating type, which, by means of an entirely novel system of differential levers actuated by a specially-coiled momentum-absorption spring, can be run up to give 600 sparks per minute with absolute reliability. Combined with it is a current distributor that permits a variation of 30° in the timing. The

of driver and driven being always in conjunction the one with the other. The acceleration of the angular velocity of the magneto armature at the moment of sparking can be in the ratio of two to one beyond that of the motor shaft, by which it is driven through a simple train; it may be made eight to one by a compound train, or even 16 to 1 if required, with a reduction of eight to one for normal running after the engine is started. This type of magneto with its distributor is, of course, a great convenience for starting, when the engine is unsuitable for working with a machine of the oscillating pattern. An electro-magnetic plug is supplied instead of the more complicated tripping-gear arrangement, the movement of the igniter being controlled and operated by a suitable electro magnet in circuit with the armature of the magneto. After being started up, neither the oil feed, nor the air supply, nor the ignition require regulation. All conditions of load, from light running up to full power, being automatically controlled by the governor, which acts simultaneously on the oil feed and on the vaporiser throttle, there is no hit-and-miss action whatever. For half speed or any other speed below the normal running at full, a hand lever or pedal is arranged to act on the governor. Starting is, of course, an arduous task in these big engines, if the usual method of cranking be employed. In the Griffin designs recourse has been taken to an auxiliary starting engine of about 6h.p. for all the models over 40h.p. In Fig. 49 the auxiliary motor can be observed on the forward pair of cylinders. It is fitted with its own vaporiser, and, when started, turns the big engine round by means of a triple contact friction drive of very large gear reduction, acting on the flywheel. In many instances this small engine would prove handy for working the deck winch. For the smaller engines up to 40h.p. a patent momentum starter is employed. In this arrangement the flywheel is free on the shaft, and is easily and rapidly rotated by means of a handle attached to a chain wheel and chain that gears with it. A friction clutch, actuated by a hand lever, is rigidly fixed to the crankshaft, and either engages or disengages the flywheel as desired.

To start the engine it is only necessary to rotate the flywheel rapidly by means of the handle, and while thus rotating, the friction clutch being engaged by means of the hand lever, the engine makes five or six rapid turns, and will then take up firing. There is little labour required to start up in this manner. In Fig. 48 the momentum starting gear and one end of the vaporiser can be clearly seen on the left. It will be recognised from this description of the salient features of the Griffin marine engine that, though it has not yet made much stir in the marine motor world, it possesses all the requirements and merits of a useful commercial engine. Lest it be thought that the design is experimental, it may be remarked that Palmer's Shipbuilding Co. patronises it, that the manufacturers have had many years' experience of oil engines, and that during the past few years the type has been fitted to a goodly number of vessels.

The Kromhout Motor.

By the fact alone that it requires no lamps, either for ignition or for the heating of the vaporiser, the Kromhout stands almost in a class by itself. Means being provided for starting on petrol and running with the same fuel until the paraffin vaporiser is sufficiently warm, and electric ignition being fitted, there is no need at all for any naked flame in the engine-room when getting under way. And for this reason the Kromhout is at the moment among the few engines that can comply with the regulations of the chief dock companies in the world, and thus enter or leave dock freely when running.

In its general appearance the engine is both robust and simple, and does not belie its construction. It is mounted with its reverse gear on a steel frame, the flywheel being forward to balance the weight. The cylinder casting, with its head, and the large crankcase, with its big inspection doors, make a group that could hardly be matched for neatness and cleanliness. On the forward end of the engine, where all the moving parts are concentrated, there is a piece of mechanism, which, though simple in itself, is apt to be misjudged as complicated at first sight. It is the governing device and exhaust valve lifter.

In principle the method of governing is the well-known "hit-and-miss" system, but it has features which are quite its own. The exhaust valve is not operated as in ordinary oil-engine practice through the motion of a cam, but by means of an eccentric rod and crosshead, deriving their movement from the half-time shaft. Attached to the crosshead is a knife-edged tappet which, under normal running conditions, lifts the exhaust valve on each upstroke. By means of an inertia or pendulum governor this knife-edged tappet is drawn to one side, when the engine speed exceeds the prearranged maximum. In this manner the exhaust valve will not open at the proper period of the cycle, and the imprisoned gases will be left inside the cylinder to act as a cushion for the piston. No fuel is permitted to enter during the next down stroke, and, the air-inlet valve being automatic, neither will air be admitted nor the exhaust gases allowed to escape until the engine shall have slowed down to its normal speed and the governor fall out of action again. It would serve no useful purpose here to endeavour to explain the action of the pendulum governor, an account of which would require much space and several illustrations. In principle it is nothing more nor less than a device for drawing the valve tappet from underneath the valve stem, and this is rendered the easier by the peculiar knife shape of the tappet.

Attached to the exhaust valve stem is a latch, which, on each down stroke, moves the bell-crank that operates the plunger of the oil pump. A spring causes the pump to fill automatically after each charge has been forced to the vaporiser, and thus on each down stroke the pump plunger is in the same position awaiting the lift of the latch. By a very simple method of limiting the motion of the bell-crank, the stroke of the fuel pump, and, hence, the fuel charge, can be altered at will. This is accomplished by a stop, which can be moved forwards or backwards by turning a conveniently-situated milled head, provided also with a locking device. It is plain that the motion of this pump, being dependent upon the motion of the exhaust-valve stem, no fuel is pumped into the vaporiser when the governor has cut the exhaust valve out of action. Yet, since the exhaust valve can only be opened at the correct period of a cycle of operations, the entry of the next charge of fuel must, nevertheless, be timed for the suction stroke. It will be seen further, from the description of the vaporiser, that this method of governing on the exhaust is the only possible one for this engine in its present design, for the temperature of the vaporiser depends upon the internal heat of the engine and not upon the heat of a blow lamp. Thus, if the hot products of combustion were released from the cylinder before the idle strokes of the engine were completed, the fresh air that would necessarily enter would considerably cool the vaporiser and affect the smooth running of the engine when the governor permitted the next working stroke.

In the same pocket as the exhaust valve, but above it, is the inlet valve. Between the two is the vaporising chamber. Under the inlet valve is placed a cone-shaped ring, thermally insulated from the rest of the engine by resting on knife-edges, and incapable, therefore, of conducting its heat away through the walls of the chamber. The fuel from the pump is delivered in such a manner that it is sprayed by the entering air and carried round the vaporiser funnel, where a thoroughly intimate mixture is formed. When the engine speed rises above the normal and the governor comes into action, it will be under-

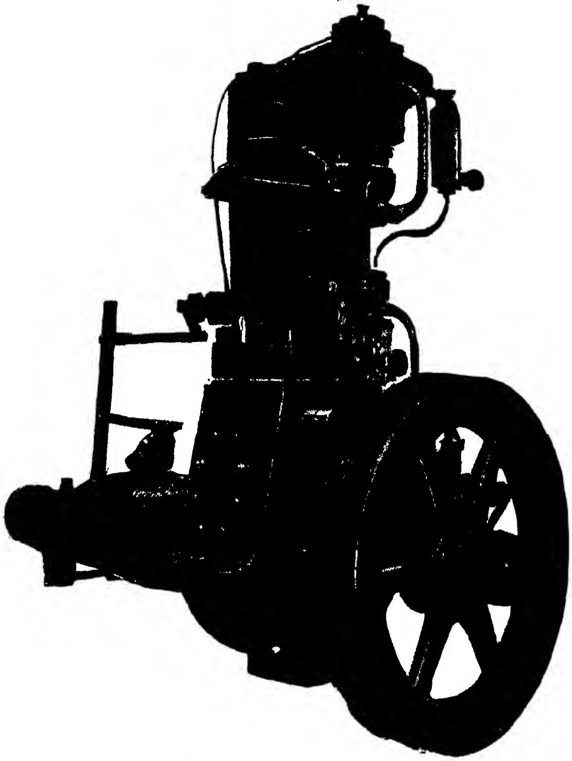


FIG. 51.—The Kromhout motor.

stood how the hot exhaust gases remaining imprisoned in the cylinder serve to maintain the vaporiser hot enough to deal with the next incoming charge of paraffin and air, perhaps some 10 or 12 strokes later, for, when there is no load on the engine, a full charge stores a lot of energy in the flywheel. Ignition is by an oscillating low-tension magneto, which possesses great advantages for such a slow-running engine as the Kromhout. From the sharp and rapid movement of the magnetic shutter a much more intense spark is said to be given by this type of magneto than from either the rotary type or from a coil and accumulator. And at such a low speed the disadvantages of the reciprocating motion are, of course, not observable. In all the Kromhout engines, moreover, the firing point is fixed, and in order that no attention shall be demanded by the ignition from unskilled hands when the engine is being started, an ingenious contrivance is added to the magneto for the purpose of setting it correctly for the first firing stroke.

For starting, petrol must first be poured into the small reservoir near the top of the engine and connected to the delivery pipe of the fuel pump The flywheel must then be turned over until the piston is at the upper dead centre, following upon a compression stroke, and, therefore, preceding the working stroke. A few strokes given to the fuel pump by hand will then provide the engine with its first charge of petrol. To draw air into the cylinder for mixing with the petrol the flywheel can then be turned for a quarter of a revolution in the direction of running. As the flywheel is smartly returned to its original position by a quick throw against the direction of running, the piston will be forced to compress the vaporous mixture of petrol and air, which, being fired by a spark from the magneto as the piston just approaches the top of its stroke, will cause the engine to start away. Gradually the small measure of petrol in the special container will be consumed, but as, during that time, the exhaust gases having been warming up the vaporiser to the requisite heat, when, after five or six minutes, the disappearance of the petrol automatically starts the paraffin feed, all the essential conditions for satisfactory working on the heavy oil will be present. But for the exceedingly rapid break obtained by the oscillating shield of the magneto, this simple, easy, and certain method of starting would be impossible. It should also be mentioned that the magneto is set to fire at the correct moment when starting up, by means of a latch, which is automatically slid into a position where it trips a special cam designed to operate the magnetic shield in the reverse direction to the normal. Directly the engine commences to run in the proper direction this auxiliary firing cam ceases to be operative. When the control lever of the reverse gear is placed in the neutral position the water circulation is automatically reduced in order that the cylinder may not be cooled too rapidly, for when the governor is cutting off the fuel supply on the light load and the engine is turning idly so many times the normal water circulation would upset the heating of the vaporiser. Bevelled gear wheels provide the reverse in the usual manner. Six sizes of this engine are stocked: single-cylinders of 10h.p., 14h.p., 20h.p., 26h.p. and 35h.p., and double-cylinder sets of 50h.p. and 70h.p., all being supplied on a bed-plate with the reverse gear as previously mentioned.

The Pasley Engine.

Two-cylinder 64h.p. and four-cylinder 128h.p. engines, developing their power at 375 revolutions per minute and similar in construction to the Pasley types described in Class V., are made

by this firm. A standard detail of the equipment of the big four-cylinder engine is an auxiliary motor for starting.

Van Rennes Motors.

Amongst the engines used so extensively for barge installations in Holland, where the network of canals unspoilt by numerous locks gives to water transport an importance which can scarcely be credited by strangers, there is no more popular type than the Van Rennes. The original models were all horizontal, but vertical types have now been adopted additionally, and because only these latter find favour in Great Britain and the Colonies they alone are described herewith. They are of massive construction, designed to turn at medium and low speeds according to their power. Built in six patterns, they include single-cylinder engines of 6h.p., 15h.p. and 25h.p., running respectively at 480 revolutions per minute, 360r.p.m., and 300r.p.m., and four-cylinder units of 25h.p., 60h.p. and 100h.p., turning at corresponding speeds as above. From Fig. 52, which represents the 100h.p. engine, it can be gathered how simple is the design. The cylinders are cast separately with removable heads and valve pockets. With the exception of the ignition details, all the fittings are on one side, the disposition of the overhead inlet valves, actuated by rocker tappets, providing the opportunity for a neat arrangement of piping, with one fuel inlet and vaporiser to each pair of cylinders. Starting is effected by pumping a charge of petrol mixture into the cylinders and firing it electrically. In order to be able easily to turn the engine by hand to bring the flywheel into the right position for starting, a small handle on the top of the crankcase is fitted to give half-compression by the movement of the exhaust valves. Once the engine has started, the exhaust gases commence to heat the vaporiser, which in a few minutes will attain the correct temperature for vaporising the paraffin fuel. When changing over from the spirit to the heavy oil, the air supply can be adjusted by throttling the air inlets with a simple movement of the rod running along the top of the valve pockets. The fuel feed is regulated by a small cock on the paraffin feed pipe of each vaporiser. Once this is adjusted, the engine needs no further attention, for the lever operating the reverse gear controls also the mixture throttle. When the lever is at neutral the engine runs at the minimum number of revolutions per minute, and for ahead or astern the lever sets the engine to the maximum number of revolutions per minute. The governor,

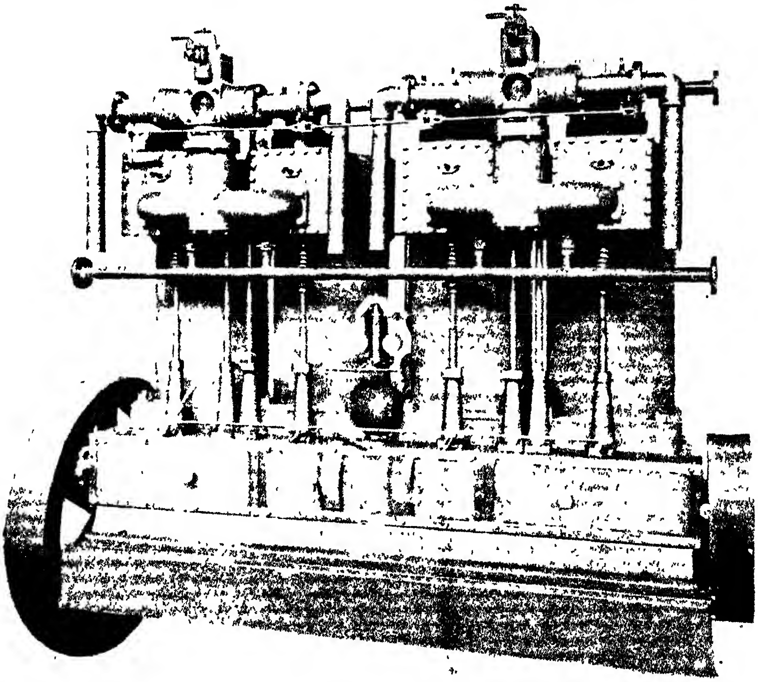


Fig. 52.—Van Rennes 100h.p. engine.

seen in the illustration, was provided to throttle the mixture, but this has now been abolished in favour of the interconnection of engine and reverse gear control. An Eisemann high-tension magneto is employed for ignition purposes. The water circulation is maintained by a belt-driven plunger pump. Lubrication is effected under pressure to all the main bearings, which are of generous proportions, the crankshaft being of large diameter and bored out for lightness. In the small 6h.p. engine the inlet valve is automatic, but in other respects the details of all the engines are similar to those of the 100h.p. four-cylinder type.

Class VII.

Suction Gas Engines. Thornycroft.

The plant consists essentially of a gas generator, a cooler and scrubber and an engine. Although the combined cooler and scrubber increase the amount of floor space occupied, they are indispensable adjuncts. The generator provides the gas, which, being obtained at a high temperature, has to be cooled in the cooler, and then in the scrubber freed from any particles of dirt which may happen to have been collected. Only after both operations is it ready for combustion in the engine.

Suction gas is really a mixture of producer gas and water gas, and derives its name from the operation whereby it is obtained in the generator. Producer gas is obtained by blowing air through a red-hot fire in an enclosed chamber, so that the two gases, oxygen and nitrogen, which are mixed in the air shall be separated. The former, coming into contact with the red-hot coal—which consists principally of carbon—unites with the carbon to form carbon monoxide. If steam be blown through a red-hot fire also in an enclosed vessel, the steam is broken up into its constituent elements, oxygen and hydrogen, and here again carbon monoxide is formed as the oxygen comes in contact with the red-hot coal. In the former case thus it is nitrogen that is left free, whilst in the latter instance it is hydrogen. Nitrogen is an inert gas, and is simply carried through to the engine, where its presence is immaterial to the combustion of the mixture, but hydrogen, being an active gas, becomes oxydised during the explosion in the cylinder, and water is again formed. At the same time the carbon monoxide is burnt completely. Both combustible gases are instrumental in the development of mechanical power from the engine, and the exhaust consists chiefly of carbon dioxide, with a certain proportion of water in the form of vapour. Whilst the constitution of suction gas must, of course, vary with different conditions over the coal grate, it may in its most general proportions be represented by the following analysis:

CO (carbon monoxide)..	21 per cent.
H (hydrogen)	15.2 per cent.
CH_4 (marsh gas) ...	1.2 per cent.
O_2 (pure oxygen) ...	0.2 per cent.
N (nitrogen)	54.2 per cent.
CO_2 (carbon dioxide)...	8.2 per cent.

It is, it will be noticed, not a very rich gas, more than one-half its volume being composed of gas that is useless for combustion, the chief effect whereof is the need for a large cylinder capacity per horse-power. Inasmuch also as the gas cannot be generated very rapidly, there is a low limit to the engine speed. From both factors it follows that the complete plant for an installation is both heavy and roomy. On the score of economy, however, so markedly is suction gas superior to steam or oil engines, that for commercial purposes, where the question of running costs is important, the entire consideration of weight and space resolves itself into a determination of comparisons with steam.

In Fig. 53 the large drum is the generator, which consists of a shell lined with firebrick for a portion of its depth. Small coal is shot in through the top until the coal space is entirely filled. Assuming the fire to be burning and steam to be obtained—in a manner which is explained later—then the steam is blown over the grate from the bottom, air at the same time being drawn in by the engine. The grate consists of a dished plate of slightly larger diameter than the brick-lined coal container, and, being placed slightly lower than it, a conical ring of red-hot coal is formed round the edge of the grate and exposed to the steam and air entering. The height of the plate is regulated by means of a rack and pinion, operated by a hand lever, moving over a locking quadrant. If the motor be running on a small load only, the big ring encircling the air holes in the drum permits a greater quantity of air to pass in and enter the fire above the level of the grate, the control of this ring being brought back to the clutch mechanism. There are two grate doors—diametrically opposed—and it is through these that the ashes are withdrawn. Although there is no hopper fitted to the generator shown in the accompanying illustration, such an arrangement is actually provided, for whilst the supply of fuel in one charge is sufficient for an entire day's work, it may be required to continue running without intermission for another day, in which case the replenishment is accomplished with the aid of the hopper. Steam is obtained from water circulating in a coil just below the grate, where the heat is always ample for the

purpose. This method also possesses the advantage that the steam supply is always ready when the generator itself is sufficiently hot to provide gas for the engine.

When the fire is first lighted, and there is no suction from the engine to assist the draught of air over the grate, a small motor-driven air-blower is brought into operation. For some time the process is analogous to that of the furnace of a steam boiler, for the coal will give off waste gases that, not being consumed by the engine, must be led away through a chimney into the atmosphere. A funnel is therefore provided at the top of the generator. When the fire is burning with sufficient fierceness, the chimney door must be closed, and with the steam blowing over the fire the engine can then be started. This is not a job that can be tackled by the mechanics or engineers, as until a steady flow of good gas is being drawn from the generator there will be no firing in the cylinders. A small petrol motor, balanced on the engine bedplate, is therefore fitted for the heavy cranking work. Its own normal position is at an inclination to the main engine, but a stout handbar enables it to be rocked past the vertical position until it is inclined sufficiently far in the other direction to tighten up the belt which runs over its own little pulley and that of the main engine. Directly the suction gas is rich enough to fire, the driving belt from the small petrol motor can be thrown on a shelf and the petrol turned off.

On its way from the generator to the engine the gas is subjected both to a cooling and to a scrubbing process. Experience has shown that there is nothing superior to the coke-scrubber and cooler, although it occupies a little more space than the plain water-spray apparatus. In the accompanying illustration the two towers next the generator are filled with coke. At the top there is a water tank from which a constant stream drips down the tower to the bottom, whence the surplus is drawn away by a pump. Both towers are similar, but whereas the gas passes up one it flows down the other. Any dirt that may have been carried over from the fire is left behind, and the gas passes then to a centrifugal drier, in which it is whirled down by a number of rotating discs and permitted to rise through a flue to the induction pipe.

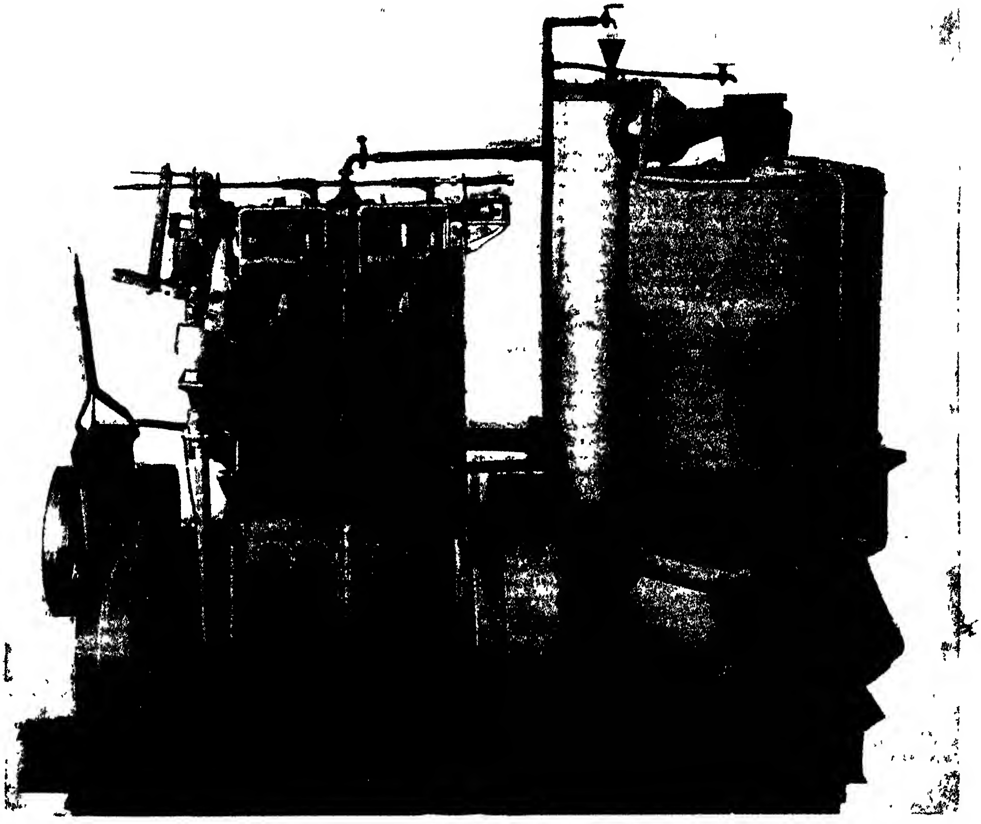
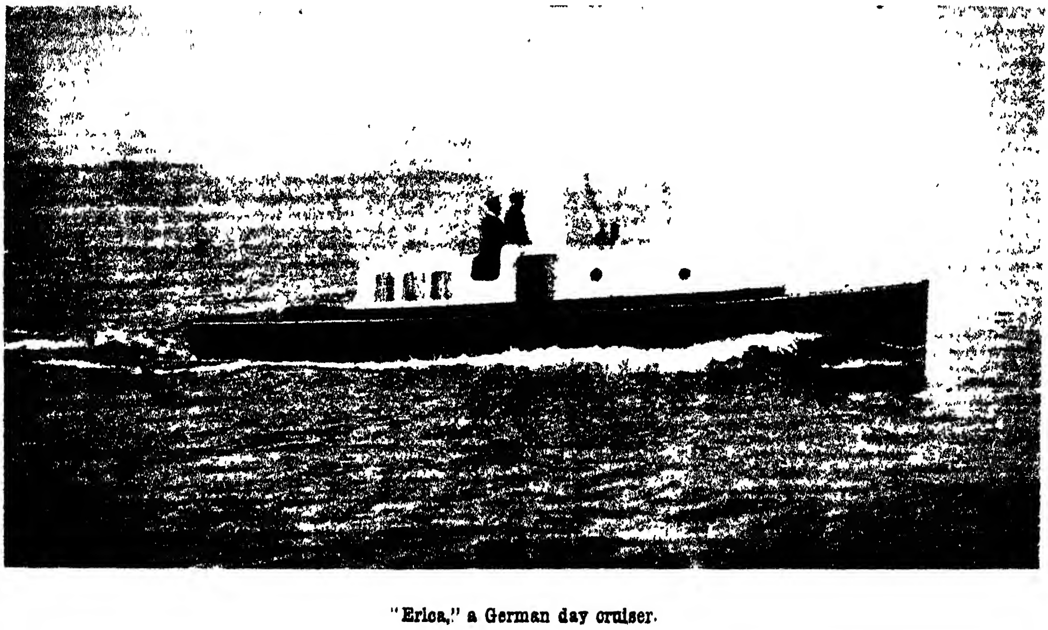


Fig. 53.—Suction gas producer and engine.

Before it reaches the cylinders it is mixed with air entering through an adjustable port. Once past the valves it is consumed in the same way as petrol or paraffin in the ordinary motor, the cycle of operations in the engine being similar, although various factors, such as the compression, are different. All the valves are situated in the head of the cylinder, which is arranged to slide off to one side after a few nuts have been slacked. This enables the valves, ignition gear and cylinder heads to be readily cleaned when desired. Inlets and exhausts are placed side by side and are operated by rocker arms, that are depressed against the pull of two light springs instead of one heavy one. Governing is performed by a quick-acting governor, which, when the maximum speed is exceeded, is arranged to grip a brass-ended fibre ring between two collars on the governor shaft. A certain amount of slip between the fibre ring and the steel collars is permitted, but not enough to prevent the former being rotated slightly as the grip of the governor tightens. The teeth cut on its body then engage with a rack controlling the throttle. Hand regulation of the governor is provided in a very ingenious manner. The linked frame seen at the top of the engine at the after end can be rocked about its lower end, and, in so doing, the upper collar on the governor shaft raised or lowered, and thereby the speed at which the fibre ring is gripped correspondingly increased or decreased. Although the vertical movement in the collar is very small, the variation in the speed amounts to about 33 per cent. of the complete range of speed of the engine. High-tension electric ignition is now fitted. The water jacket on the cylinders consists of a steel coat shrunk on the cylinder trunk. For starting, half-compression cams are brought into engagement, but they are automatically cut out when the proper speed of the engine is attained. An exhaust valve lifter is also provided in order that the engine can be turned round by hand. An oil tank is attached to the engine frame at the after end, whence the oil is forced under pressure to some of the bearings, the remainder being lubricated by gravity feed from a tank at the side of the engine. A particularly interesting, though trivial, detail is the discharge of the water from the cylinder heads through an open pipe into a funnel just below, by which means the circulation can always be verified. Although in the Thornycroft works only two models, a four-cylinder 60h.p. and a two-cylinder 30h.p., are constructed, larger sizes are made to the same general design in the Beardmore works on the Clyde. It was a Beardmore suction gas engine of 550h.p. that did so well in H M.S. "Rattler" during the season of 1908.



"Erica," a German day cruiser.

RACING ENGINES.

Introduction.

It is not too much to say that the system of rating power according to the bore of an engine has completely revolutionised the design of motors, both ashore and afloat. The system, so far as marine motors are concerned, first made its appearance at Monaco in 1908, while a formula depending only upon bore, not on stroke or revolutions, as had formerly been the case, was at the same time introduced by the M.M.A. in this country. How great the influence of a rating rule can be on designs, and how it can accelerate or retard progress, can only be realised by a study of types evolved respectively under the old and the new régime.

Take, for example, the old French engines rated entirely on bore and stroke. The obvious method of cheating rules was to force up the revolutions to the last possible limit, and, as nothing was said about weight, to cut factors of safety down to vanishing point. The result was an exaggerated development of the motor-car engine of that day, and one that quickly succumbed to the more strenuous conditions encountered at sea. Experience had not then taught the necessity for special lubricating and cooling arrangements, for effective insulation, or even for adequate bearing surfaces, and French racing boats at once acquired a reputation for short and furious bursts of speed, alternating with breakdown and breakup of every description.

Meanwhile, an exactly opposite tendency was discernible in England. Starting a little later, and, consequently, having the warning of Continental experiences to guide them, our own M.M.A. evolved a power-rating formula that was the very antithesis of the French rule in that it included revolutions. Nothing, therefore, was to be gained by running fast, and in an effort to obtain propeller efficiency a heavy, slow-running type was developed that made an infinitely better marine job. For certain purposes, indeed, the type was ideal, but, as is often the way in such cases, it was carried to too great an extreme, and engines of large dimensions gave altogether disproportionately low power; the intrinsic advantages of the internal-combustion engine were, in fact, to a great extent lost, and the distinguishing features of compactness and lightness, as compared with steam engines and boilers, suffered accordingly.

The racing of 1907, however, clearly demonstrated that the inclusion of revolutions in any power-rating formula was impracticable, owing to the impossibility of checking them during a race, and accordingly the old formula was abandoned. It was then seen that, by leaving out the factor of strokes, designers would be compelled to increase that dimension to its utmost limit, and that, consequently, the tendency towards inordinately high revolutions would be automatically checked by the limits of piston speed. A power-rating formula was, therefore, evolved, depending solely on bore, and a very similar rule was brought out at the same time for the Monaco meeting. From the first, the M.M.A. had indirectly provided against the construction of undesirably light motors by their rating formula (not power rating), but in France this factor was at first omitted, though included at the Monaco meeting of 1908 in the shape of a minimum weight restriction on the whole boat. And the result has been an improvement that can scarcely be credited. Engines of a size that, three or four years ago, would have developed 15 to 20h.p. now give as much as 60h.p., and where 11 knots would at one time have been considered a fair speed, 18 or more are now obtained with hulls not a whit less seaworthy.

But the old M.M.A. rule, though now obsolete, did excellent service, for it freed designers from the consideration of many complex problems and left them leisure to consider such matters as the perfecting of lubrication systems and the improvement of installation arrangements generally. In short, it enabled them to turn their attention to the formerly baffling problem of how to keep an engine running at full power for an indefinite period. To the car owner the problem will be more intelligible if a boat be considered as an automobile travelling up a steep hill all day on bottom gear. The knowledge gained was invaluable, and when the variants of a simple "bore formula" came into force, marine motor engineers were in a position to tackle the problem of getting the most out of a cylinder of given size, without losing sight of the essential features of a marine engine. To have put such a formula before them at an earlier date would have been equivalent to placing firearms in the hands of a child, and would have produced an unreliable, weak and freakish type of engine that would have brought discredit on the whole industry. With this brief retrospect, we may proceed to discuss racing engines as we know them to-day.

English and French formulæ, differing in matters of detail, have now been merged into the new International Motor Yacht Racing Association's formula, in which power is a function of the 2.4th power of the bore. It may be as well to mention here, though the matter is dealt with at length in another section of this book, that this index has been chosen in preference to the square of the bore to neutralise the advantage that a big engine gains over a small one under the latter conditions. The point does not, however, affect the subject dealt with in this article. We have before us the problem of producing an engine not exceeding a certain bore, that shall give the greatest possible amount of power, and, at the same time, embody those features which experience has proved essential in a motor destined to run at the utmost limit of its capacity for protracted periods.

Preliminary Considerations.

Revolutions.—The first point to be decided is the speed at which the engine is to run. At the outset it may be stated that considerably higher revolutions may be advantageously employed than would have been the case a few years ago. For this we are indebted to a great extent to the great increase of knowledge regarding high-speed propellers. The adoption for warships of turbines running at 1,200 revolutions is probably mainly responsible for this, as it has compelled such firms as Messrs. Thornycroft and Yarrow to reconsider the whole subject, and the experience gained cannot have failed to have been invaluable when applied to motor craft. Some such speed as this may, therefore, be taken as approaching the limit to which it is desirable to go, and the question resolves itself into a choice between designing an engine to run at about this rate, and adopting a much higher speed with a geared-down propeller.

Gearing-down may, of course, be effected either by gear wheels (in which case the advisability of driving off a specially-constructed camshaft must be considered), or by means of a chain drive, and the choice between the direct and geared drive must depend upon the designer's estimate of gain in propeller efficiency as opposed to loss in transmission, with the additional factor of the extra power that may be gained from the engine by running it at a greater speed. The loss in gearing might well amount to as much as 20 or 25 per cent. after a few months of hard work. Chains of the best type, running in an oil bath, have, when new, an efficiency as high as 94 per cent., though this would fall to 90 or 85 per cent. with constant use. We do not know of any existing example of a chain drive in a racing boat, though we expect to see one installed in an 8-metre racing cruiser in 1909. Of this more anon.

"Lanturlu," a competitor at the last Monaco meeting, was fitted with a gear drive, but no very accurate comparison was possible between her and others of her class, as neither the hull nor the engine was of such an extreme type as most of her rivals, but, so far as could be judged, the system seemed distinctly advantageous.

Stroke.—Having settled the question of revolutions, the stroke is the next factor to be determined. Obviously, this must be as long as possible, and the limiting consideration will be the piston speed at which it is possible to run, which, again, will depend primarily upon the weights of reciprocating parts. For an engine running at about 1,200 revolutions, the maximum for a big engine, for example, a motor of 6in. bore, which approaches the limit of the international small racer class, has been about 8in. Special "4-inch" motors have since been constructed with as long a stroke as this. Exhaustive experiments with crankshafts of various throws were carried out last summer with a Metallurgique motor of about 4⅛in. bore, built specially for the 8-metre racing cruiser class, and brake tests showed that most power was obtained with a stroke of just over 6⅜in. This engine develops, astounding though it may appear, over 60h.p., and with bigger valves and longer stroke 80h.p. will be obtained.

Compression.—It is necessary that the compression to be employed should next be decided, for, if this be very high, it will materially affect the design of the cylinder head, it being impossible to obtain very high compression if large valve pockets are used. It is on the question of compression that the opinion of the best designers seems to vary most. About 85lb. to 90lb. is considered by the majority as far as it is desirable to go, and brake tests with varying compressions have in many cases proved these figures to be more or less correct. On the other hand, a notably successful motor, the Sizaire-Naudin, is, we believe, run at over 100lb. compression. The question is one best settled by actual experiment after the motor is built, packing pieces being placed under the cylinders or above the big-end brasses as may be required, while a certain amount of variation may, of course, be obtained with dished valve caps.

When such experiments are contemplated, it is, however, essential, as already hinted, that the design of the cylinder head be such that the compression can actually be obtained. Finally, it must not be forgotten that every extra pound of compression employed involves an enormous increase of the tendency to overheat, a trouble that can only be got over by the most elaborate precautions in any high-speed marine motor. Indeed, in large engines it becomes so acute that it probably would not pay to attempt to run at more than 85lb. compression in a cylinder of 6in. bore or more, though as much as 120lb. to the square inch has been successfully employed in small engines.

Valves.—In determining the dimensions of valves it cannot be too clearly kept in mind that, from the point of view of efficiency, the best thing to do would be to lift the cylinder head

off at every stroke. That is not, of course, possible, but, as an approximation to this ideal, valves should be made as large as possible. From 80ft. to 100ft. per second is considered about the best speed for the gas through the valves, and though horse-power—revolution diagrams—indicate that no very great loss is experienced from wire drawing until a velocity of 140ft. per second, so excessively high a speed should be avoided whenever possible.

On this basis the valve sizes can be calculated in the usual way, and it only remains to arrange them in the cylinders. In this connection, valve-pocket design affords a stumbling-block that has proved the undoing of many an otherwise excellent motor. Assuming that the valves themselves are sufficiently large, it occasionally happens that they are designed to work in quite small valve pockets, leaving but little clearance between the periphery of the valve and the walls of the pocket. In this case the gas is most effectively throttled between the valve and the cylinder, and the wire-drawing effect is as bad, or worse, than with small valves.

the cylinder head. Putting this aside, there remain four possible systems. First, the inlet and exhaust may be placed side by side in one pocket, as is the standard practice in most engines of to-day, and which admits of a moderately high compression and undoubtedly gives the most silent and accessible engine; second, one valve may be situated over the other, as in the Thornycroft motor of "Gyrinus," where the inlet is over the exhaust, or in the Metallurgique engine, of which the exhaust is over the inlet; third, the exhaust may be in a pocket by itself, with the inlet valve right in the top of the cylinder head, vide the big Mercédès racing engines; and, fourth, both inlet and exhaust may be in the cylinder head.

The first system can be recommended for general convenience and absence of noise; the second provides an effective method of cooling the exhaust valve by blowing the cool, incoming gas on to it; the third admits of an almost unlimited size of valve and allows a most efficient scavenging action to take place, besides allowing of an excellent water-jacket design; and the fourth

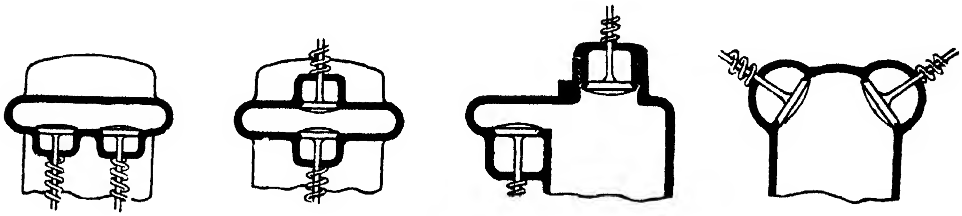


Fig. 1.

Now, as to the arrangement of the valves themselves. It is, of course, perfectly easy, as explained on another page, to calculate the size of valve required to give a certain speed of the gas for a predetermined rate of revolutions, and having arrived at this, it only remains to decide how the valves are to be arranged. In the first place, given a certain valve area, it must be decided whether this is to be embodied in a single valve or distributed between two. For the inlet, which will, of course, be mechanically operated, there is no objection to a valve of any size, but exhaust valves, being subjected to excessively high temperatures, are liable to overheat and get out of shape, and in very large engines, exceeding 7in. bore, it is probably the best practice to employ two exhaust valves. Some system of pockets has to be arranged for the valves, and in a high-compression engine it may at once be said that an arrangement of inlet and exhaust on opposite sides of the cylinder is not permissible, as the large size of the pockets makes it impossible to obtain sufficient compression, even if the piston be carried almost into contact with

makes a higher degree of compression possible than can be obtained with any of the foregoing systems. The last is probably the best arrangement from the view of pure efficiency, but it has the drawback that, to obtain an efficient water-jacketing system, the valves must be free to drop into the cylinder should their stems break, and should such an accident occur, it would, in all probability, result in the wrecking of the whole engine. The four systems are illustrated herewith, and it must be left to individual taste to decide which to adopt.

One word of warning regarding the method of operating the valves in the last case. One is tempted to pivot a rocking arm between the two valves and to operate one of them by means of an undercut profile of the cam. This system was to be seen on some of the old Darracqs and Fiats, but in the light of more recent experience it is not to be recommended, as it does not permit of an inlet valve opening until a perceptible interval after the closing of the exhaust valve of the same cylinder. Exactly the same arrangement was to be found on the engine of "Dixie II.," win-

ner of the B.I. Trophy race of 1908, but in this case the maximum speed of the motor was only 950r.p.m. Had the timing of the valves been different (assuming always an efficient cooling system), it should have been possible to run this engine a good deal faster, for, as will be seen shortly, to obtain the best results at high speed, a certain amount of lap is required on valves.

Valve setting.—This is a matter concerning which no definite rule can be laid down. The best setting for the valves on any particular engine can only be determined by experience and experiment, the angles varying considerably with the valve diameter, speed, design of valve pockets, and length of stroke. Broadly speaking, however, both the inlet and exhaust valves should open early and close late in a high-speed racing engine, these characteristics becoming more apparent as the revolutions go up. The illustration shows roughly the arrangement.

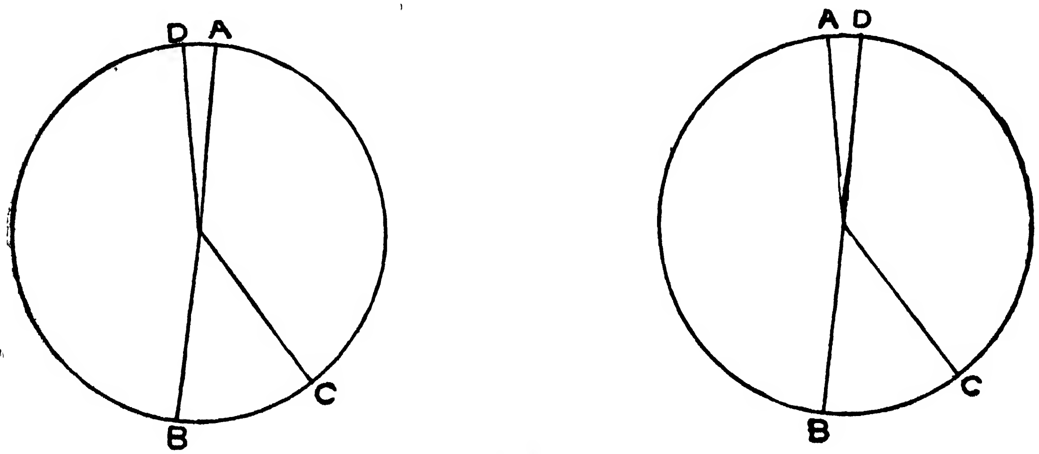


Fig. 2.

The inlet here begins to open before the exhaust stroke is completed, and the exhaust does not close until after the piston has begun to descend on the suction stroke. From this it will be perfectly obvious that such valve setting makes it quite impossible for an engine to be run dead slow. If this were attempted, the exhaust gas would fire the fresh charge before the inlet had time to close, and there would be a fireback into the carburetter. For this reason such an engine is rather hard to start, and to get over this difficulty an excellent arrangement is to be found on the Sizaire-Naudin motor, in which the inlet cam can be moved under its tappet, giving a variable cam profile according to the position of the throttle. With the throttle only a little open, the setting of the inlet valve is entirely altered. It does not open till the exhaust is closed, and it does not shut until the piston is some way on its up-stroke, so that part of the charge is returned to the induction piping, the result being that the compression is very much lowered for starting. We illustrate the motor in question herewith, and can most strongly commend the system to designers of all racing engines of the future.

Auxiliary exhaust valve.—The idea of fitting ports in the cylinders to be opened by the piston at the bottom of its stroke is, of course, very far from new. It was tried in the early days of motorcycling with great success. In larger engines, however, some trouble has been experienced through getting exhaust gas back into the cylinder towards the end of the suction stroke, and for this reason the system has not come much into vogue. It appears likely, however, that auxiliary exhaust valves will in future become very common, for, given a satisfactory method of getting over the difficulty just named, there is everything to be said in favour of them. An enormous amount of back-pressure is done away with, and, most important of all, the ordinary exhaust valve is relieved of a lot of work, is not so subject to pitting, and has not anything like the same tendency to overheat. Probably the most successful example of the application of this principle is to be found in the engine of "Dixie II." The bore is 7¼in., and, without special arrangements for cooling, it would have been quite impossible to run such a motor even at 750r.p.m. through a long race.

We have just referred to the necessity for preventing exhaust gas getting back into the cylinder through the auxiliary port during the suction stroke. This has been most successfully got over in the case of "Dixie II." by putting mechanically-operated mushroom valves just outside the ports, these valves being open during the exhaust stroke, but closed during the suction, thus making it quite impossible for any of the exhaust to blow back.

General considerations.—From the above it

will be clear how the principal characteristics of a racing engine must be arrived at. Other questions of design will follow more or less normal lines, though the dimensions of all parts must, of course, be calculated to be of sufficient strength to withstand the additional strains due to the extra power obtained from the cylinders as compared with ordinary motors of the same bore, so that bearings, etc., must be of exceptionally large size.

Weight.—One of the most important factors to be decided is the weight, not so much of the engine as a whole, though that is very important in an unrestricted racer, but of the reciprocating parts, for, unless these be extremely light, the combination of long stroke and high revolutions will be found to set up fearful strains and excessive vibration, which will be fatal to the efficiency of the engine. Pistons must, therefore, be of the finest possible material and must be machined inside as well as out to the limit demanded for strength, and a good deal may be saved by boring out the lower part of the trunks. Gudgeon pins should be hollow, and the connecting rods, if of H-section, should be bored out in the web, and also in the bosses that take the brasses. While dealing with this part of the subject, it will, perhaps, be as well to state that a circular section is the strongest, for a given weight, for a connecting rod, and it is, therefore, the best to adopt, the rod being, of course, hollow. One of the finest examples of weight-saving in reciprocating parts is to be found in the Metallurgique motor for the 6½-8-metre racing cruiser class. The bore is 106mm. ($4\frac{1}{6}\frac{1}{4}$in.), yet the weight of a piston and connecting rod complete is only 5⅜lb.

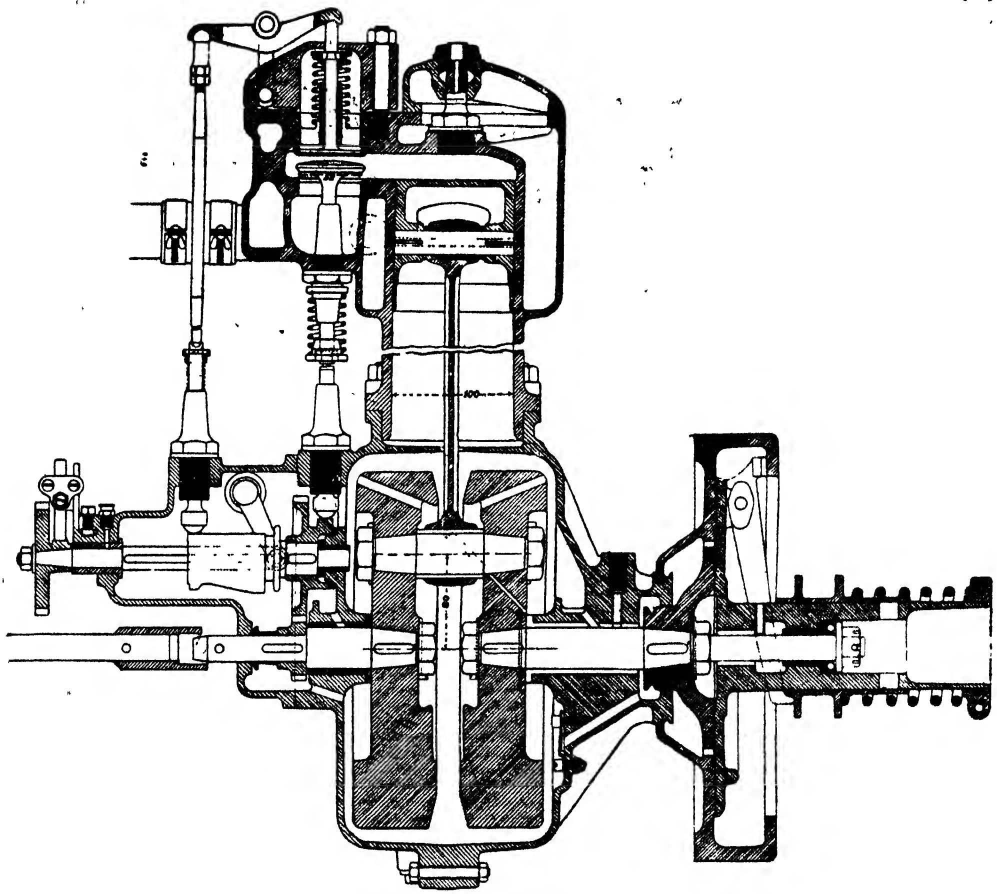


Fig. 3.—Sizaire-Naudin motor.

The weight of the valves, too, is a factor that must not be neglected; they must be as light as they can possibly be made, consistent with strength. A heavy valve will not close quickly enough at high speeds, and may frequently be heard to chatter violently, however strong the valve springs may be.

Where the weight of an engine as a whole has to be considered, as in an out-and-out racing boat (not in a restricted class with a minimum weight limit), a great deal more depends upon the design. There can be little doubt that a V engine can be made the lightest for a given power, and, unless other considerations outweigh it, there can be little doubt that this type is the best to adopt where weight-saving is of very great importance. But there are, of course, many little ways in which weight can be saved. The crankshaft can be hollow; in spite of the expense, it may even pay to bore out the camshaft, as is done in the big Mercédès motors, and there are a hundred little fittings which can be cut down in weight without any sacrifice of strength by the judicious use of a drill. Only an ounce, it may be, will be saved here and there, but it is surprising how scientific paring of details may save hundredweights on the complete engine.

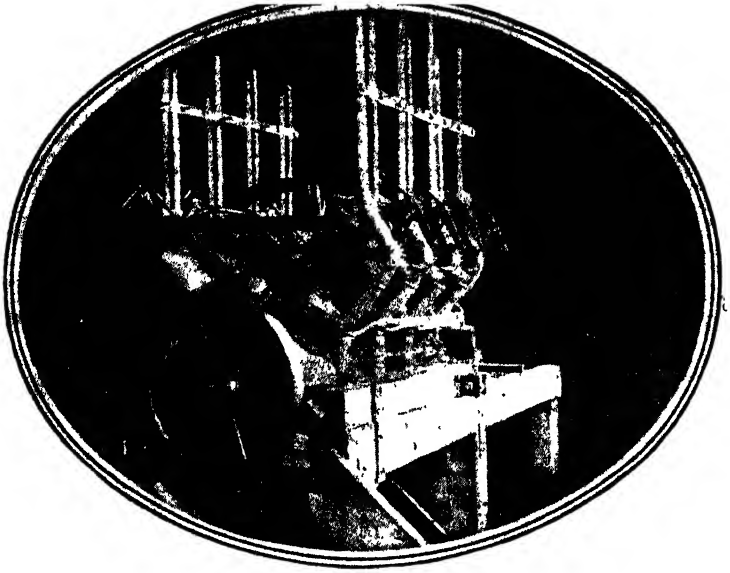


Fig. 4.—"Dixie II.'s" motor.

Advanced centre construction, or, as the French have it, "cylindres desaxées," has been adopted by one or two makers of racing motors, notably the Mors and Metallurgique firms, the latter especially claiming that the admittedly wonderful power obtained from their engines is to be attributed to this system. The 106mm. engine of the latter make, already referred to, has an offset of no less than $1\frac{7}{8}$in., and, to compensate for the increased speed of the piston at the top of the stroke, the camshaft is set $\frac{7}{8}$in. out of line with the valve tappets, so that the valves are opened very rapidly. We are not prepared to pronounce definitely for or against the system. It certainly has its advantages, but that an equally good motor can be built on ordinary lines would appear to be proved by the performance of the Napier cars at Brooklands in competition with the Metallurgiques. One point must not be overlooked. With a desaxée cylinder there is a more sudden reversal of stress on the sides of the big-end brasses at the bottom of the stroke than there is with an engine having its cylinder axes in line with the crankshaft axis.

Cooling.—However well an engine may be designed in other respects, it is not too much to say that its success or failure depends entirely upon the efficiency of its cooling arrangements. It must be understood from the start that ordinary water-jacketing systems that have done well enough on engines of older type are quite inadequate to the requirements of "high-bred" motors. Even in a four-inch racing motor extreme care is necessary in the jacket design to efficiently cool the cylinder head and exhaust valve pocket, the seating of the valve requiring the most careful attention of all. Water-cooled valve caps are, in our opinion, desirable on an engine of this size. They have given wonderful results on the 26h.p. class Napier cars at Brooklands, and for marine work they are almost essential. For large cylinders they become an absolute necessity if the motor is to run successfully at full power. We have seen many engines so fitted, but in some cases the efficacy of the caps has been greatly reduced by the absence of proper circulating arrangements, it being common practice to merely by-pass them from the main water jacket. Such an arrangement only too fre-

quently results in steam locks, when the caps become almost useless. By far the best practice is to have a separate pump and an entirely separate circulating system for the valve caps.

The crankcase.—In more than one racing engine very serious trouble has been experienced in lubricating the main and big-end bearings, and where seizing and breakage has occurred it has nearly always been attributed to a faulty lubrication system. In the old days of splash and drip lubrication, this diagnosis was no doubt usually correct, but to-day, when forced lubrication is almost universal, the trouble is, we think, more frequently due to the oil losing its lubricating properties through excessive heating than to any defect in the supply. It is not generally realised how hot the interior of a crankcase is liable to become in the course of a long run—far hotter in a boat than on a car, as in the former case there is little or no air draught to assist the heat to disperse. Curiously enough, some engines seem to have a sharply-marked, critical speed, at which the crankcase remains reasonably cool, while a very slight increase of speed, maintained for 15 minutes or so, suffices to overheat the crankcase badly. We could name a boat, whose engine, of about 60h.p., could be relied upon to run all day at 920r.p.m., but which, if accelerated to 950r.p.m., used to heat badly in a few minutes, and lost a lot of power. We speak in the past tense, because special cooling arrangements have since been fitted to the crankcase, and the motor can now be run at full speed without the slightest trouble.

Broadly speaking, there are two distinct ways in which this overheating of the lubricant, due principally to gas getting past the piston rings, may be overcome. The oil itself may be cooled by being passed through a condenser on its way to the bearings (in a complete forced-feed system), or the whole interior of the case may be cooled by drawing air through it. The best arrangement of all is probably a combination of the two systems, though this should only be necessary in engines of 6in. bore and upwards. An extremely simple, and, at the same time, perfectly effective, method of ventilating the crankcase is to arrange for the air intake to the carburetter to draw from the interior. A sufficiently large pipe must, of course, be fitted to allow air to enter the case, and to prevent too much lubricating oil getting into the induction piping a baffle plate and gauze cover must be fitted over the suction. We say "too much" lubricating oil advisedly, because, in more than one case, notably on "Gyrinus," a certain amount of lubrication of the fuel has been found distinctly beneficial, affording an excellent method of oiling the cylinder walls.

Exhausting the crankcase.—An idea that will be embodied in one of the new 8-metre racing cruiser engines next year is to keep a pump always running that shall draw all air and gas out of the crankcase (no vent pipes will be fitted), and so keep it always clear of the hot exhaust that gets past the rings. This, however, is not the only object. The engine is to run at exceptionally high speed with a geared-down propeller, and the designer hopes to save a good deal of power by thus doing away with the churning action of the cranks against air in the case. Anyone who has had any experience of running brake tests with a fan dynamometer will know how a small fan will absorb power at high speed. A fast-running crankshaft, particularly if the stroke be long, may be regarded as a fairly powerful fan dynamometer, and, by eliminating this absorption of power by exhausting the crankcase, it is possible that a very appreciable saving may be effected.

Sparking plugs.—A matter of detail that is apt to be overlooked amidst a number of seemingly far more important considerations is the question of sparking plugs. It must be remembered that, in a high-speed, high-compression engine, the temperature of the inside of the cylinder is always very high; again, assuming that high-tension magneto ignition be employed, the high speed will result in an abnormally fierce spark, and with these two factors combining against them towards the same end—overheating—only specially-designed plugs can be relied upon to stand up to the work, and then only if they be so placed as to gain the maximum benefit of the surrounding water jacket, and should they be also exposed to the rush of cool, incoming gas.

Lubrication.—Last, but very far from least, we come to lubrication. It may be accepted as an axiom that only a complete forced feed at considerable pressure can be entirely satisfactory. There should be a feed to each main bearing and thence to the big-ends through the crank webs and again to the gudgeon pins, and, in addition, there should be a feed to each piston. A sump should be provided in the bottom of the crankcase, whence the oil should be drawn by a pump, through a condenser as already indicated, and then be supplied to the bearings.

Much has been said regarding the unreliability and tendency to overheat and generally give trouble on the part of racing engines. Where trouble has occurred in the past, it has always been due to bad design, to ignorance, or neglect of one or more of the precepts set out above. We know from our own experience that, without adequate cooling and lubricating arrangements, high-speed, high-compression engines do give endless trouble, and we also know that, by proper design, no trouble whatever need occur. Such an engine may, in fact, be placed in the hands of any intelligent amateur owner, and, so provided, he will have at once a perfect racing machine, while, at the same time, by not opening the motor out, it may be used perfectly well for ordinary cruising work. The fallacy of regarding all racing engines as "freaks" is every day being more clearly realised in motor-car circles, and already the same is, to a certain

extent, true of marine motoring. For years designers have failed to get more than about half the power they might have obtained from engines of given size. The principle of rating by bore both ashore and afloat has served to show the latent possibilities of the internal-combustion engine, and, as stated at the beginning of this article, has effected practically a revolution in design, which cannot but radically affect all motors intended for pleasure launches. The pure racing engine is probably still far from finality. And now, having briefly touched upon the more important problems that beset the designer of racing engines, we may turn to some practical examples of the type.

Sizaire-Naudin Motor.

One of the first firms to seriously tackle the design of special engines was Messrs. Sizaire-Naudin, who achieved phenomenal success in the voiturette classes ashore and also afloat in the dinghy class at Monaco with the boat "Sizaire-Naudin." We have selected this as perhaps the finest existing example of the very small racing engine. An illustration of this motor has already appeared (Fig. 3); the bore is 100mm.—just under 4in.—and the stroke 160mm. ($6\frac{1}{4}$in.). In the boat this engine was run at 1,300r.p.m., at which speed 11.5h.p. was obtained, though on the test bench no difficulty was found in forcing it up to 1,800r.p.m., at which speed $16\frac{1}{2}$h.p. was obtained. Now, even at 1,300r.p.m., the piston speed is very high—1,365ft. per minute—and it is quite obvious that such a figure would not have been reached, much less the higher speeds involved by 1,800r.p.m., were not the moving parts extremely light.

From the piston speed just given the need for enormous valves at once becomes apparent, and a glance at the illustration, which is approximately to scale, shows the relative sizes very clearly. The valve diameter is 52 millimetres (2.7in.), or more than half the bore, and the lift is 9 millimetres (.36in.). It will be interesting to work out the velocity of the gases through the valves. We will call this v, and the area of the valve opening a; also the piston area may be indicated by the letter A and the speed by S.

Obviously, $v\,a = A\,S$ or $v = \frac{A\,S}{a}$

Now, $A = \frac{\pi}{4} D^2$ (D being the diameter of the piston) = 12.56 square inches, S we have already seen = 22.75ft. per second, and a is, of course, the product of the valve circumference and its lift, or $\pi \times 2.7 \times .36$ square inches = 3.15 square inches.

Substituting these figures we have :—

$$v = \frac{12.56 \times 22.75}{3.15} = 92\text{ft. per second.}$$

This is quite a normal speed for the gases, anything between 80ft. and 100ft. per minute being considered correct.

As regards valve setting. The exhaust opens rather early and closes only after the piston has got well started on the suction stroke; the inlet opens just after the dead centre (so that both valves are open together for a very short period) and closes very late. That, at least, is the arrangement when the motor is running all out. With this timing there is a great tendency to fire back at low speeds, and so a graduated inlet cam is provided. It is carried on a sliding sleeve on the camshaft, and by shifting this sleeve a varying cam profile is brought under the inlet tappet. By thus altering the lift of the valve a throttle is provided, and, in addition, a variable compression device is obtained—a very desirable feature, for the compression is enormous, and the writer has tried in vain to pull one of these little engines over without bringing the release device into play. This consists of an extension of the inlet cam that is brought into action during the compression stroke; that is to say, the inlet valve is held open very late indeed, so that part of the charge sucked in is returned to the induction piping. In this way the compression can be made as light as is desired for starting.

The compression when the motor is running all out is extremely high, approaching about 120lb. per square inch. Motors have, of course, been run at higher compression than this, but for continuous work even the figure given is rather exceptional, and has, probably, only been adopted in the present case because the engine is a very small one. For the same reason no very special precautions have been found necessary with regard to the cooling and lubricating of this motor. The jacket is, as may be seen, large and well designed, especially round the exhaust valve. Splash lubrication is relied upon, but has been arranged with very great care. The crankcase is square in cross section; this cannot be seen from the drawing, and the result is that a practically constant splash feed is maintained by the flywheels, irrespective of the actual quantity of oil (within limits) in the case, any excess being piled up, so to speak, in the corners of the case. In addition, a drip feed supplies the main bearings, whence the oil is passed by centrifugal force to the big-end.

A Thornycroft Engine.

Next may be considered a less extreme type of motor: the Thornycroft engine installed in that very successful competitor in the 8-metre racing cruiser class, "Gyrinus." It is a four-cylinder model of 4 3-16in. bore (106mm.) by 5in. stroke, and, it is interesting to note, is almost exactly similar, except for a slight increase of bore, to the Thornycroft car engines that ran in the "Four-inch" Race in the Isle of Man. The cylinders are cast in pairs, and, to give the necessary compression and also to assist in cooling the exhaust valve, the inlet valves are situated over the exhaust. Now, this is, of course, in direct opposition to standard Thornycroft practice,

which is to place the valves on opposite sides of the cylinders, and so it is that we find, as in the illustration, that the inlet tappets are worked off a separate camshaft on the other side of the engine. The motor is run at 1,250r p.m. in the boat, at which speed it develops about 40h.p., and so here again the weight of reciprocating parts becomes of very great importance, and, accordingly, we find valves and connecting rods are extraordinarily light; nor is there any superfluous metal in the pistons. The valves are very large, 2¼in. diameter, so that they approach the size of the Sizaire-Naudin motor, though, the stroke of the English engine being an inch shorter, it is obviously not necessary for them to be quite so large. The valve setting, while a little out of the ordinary, is not so extreme as in the French engine. The exhaust opens when the piston is half an inch off the bottom of its stroke. The inlet opens almost immediately after the exhaust is closed, so that there is no actual lap on the valves, and remains open for exactly half a revolution. The accompanying diagram shows roughly the arrangement, though the angles are not absolutely accurate.

On the question of compression, also, the engine now under consideration is a compromise between the normal and the extreme, the actual figure being 80lb. per square inch. But to return to structural details. The valve springs are of exceptionally large diameter and are simply hooked into slots in the valve stems instead of the usual collar and cotter arrangement, whereby some weight is saved. The connecting rods are of circular section and hollow, and especially at the upper end, where the inertia forces are most apparent, as light as they well can be. The gudgeon-pin bearing is ⅞in. diameter by 2in. long, while the big-end is 1⅞in. by 2¼in. There are five rings on the pistons: four at the top and one at the bottom, to make quite sure that no oil shall get past, any fouling being, of course, fatal in the cylinder of a high-compression engine.

Lubrication is very thoroughly carried out. There is a sump in the bottom of the crankcase, from which oil is taken by a small gear-wheel pump and delivered to each main bearing. Thence it passes through the crankshaft, which is hollow, to the big-ends, from which it is thrown to the gudgeon pins and pistons, returning to the crankcase.

Water circulation is maintained by a gear-wheel pump, which delivers to each pair of cylinders between the exhaust valves, leaving, as usual, at the highest points of the jackets. The carburetter is an extremely simple one and is specially designed to give the correct mixture at all speeds with a minimum of adjustment. A single lever operates the throttle and extra air inlet and also controls a needle valve in the jet. The induction piping, 2in. in diameter, is simply taken in two branches of very fair curves to the induction passages cast in the cylinder heads. The inlet valve caps, we omitted to mention, are secured in pairs by four-armed dogs, each held by a single nut.

Ignition is by Simms high-tension magneto,

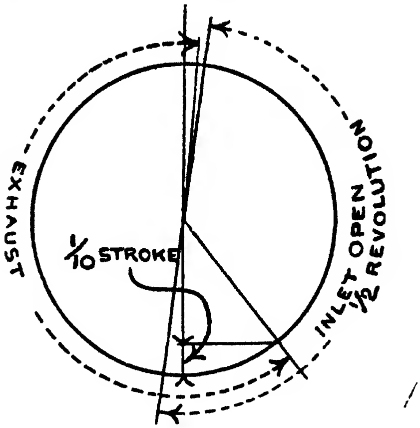


Fig. 5.

no other system being fitted in duplicate. The weight of the complete motor, except only the exhaust piping, is 4cwt. 56lb.

Metallurgique Marine Motor.

Another engine of the same size and built for the same class now comes under notice—the Metallurgique. The makers of this motor were among the first to give special attention to the problem of extracting the maximum power from the minimum bore, though the English 8-metre racing cruiser "Sea Dog" affords the first instance of one of these engines being installed in a boat, and their practice, therefore, deserves the closest attention, representing, as it does, the outcome of a long course of experimental work in which expense has scarcely been considered.

For a bore of 106mm.—4 3-16in.—the stroke is enormous—171mm., or 6¾in.—and at 1,300r.p.m. over 60h.p. is obtained, which is probably the highest that has been got out of a marine motor of this size. It is remarkable that this power was developed with no more than 85lb. compression, which, again the result of exhaustive experiment, has been found to give the best results in this particular motor. The valve diameter is 2⅝in. and the lift about ⅝in., which, calculation shows, gives a speed of about 95ft. per second to the gases, and, finally, the cylinders are offset or desaxée to the extent of 1⅜in.

It remains to consider how so much power is obtained, and on investigation it will be found that a number of details combine to produce the result stated. The extreme length of stroke is, of course, to a great extent responsible, but it has only been possible to make use of this to the best advantage by cutting down the weight of reciprocating parts to the last possible limit. A

Metallurgique piston and connecting rod has been inspected by us in reference to the matter of weight-saving; as we have already stated, the weight of piston and rod complete is but 5¾lb. That sufficient strength can be obtained on this weight is little short of marvellous, and is only rendered possible by the use of steel of very great strength; indeed, we are informed that the tensile strength of the steel used for these connecting rods is as great as 120 tons per square inch.

The desaxée principle, it is claimed, is to a very great extent responsible for the high power of this engine, the theory being, apart from the lessening of side thrust on the cylinder walls, that the rapid movement of the piston at the beginning of the power stroke enables the expansion of the gases to be more efficiently utilised. In this connection it must not be forgotten that high piston speed at the beginning of the stroke will materially affect the relative speed of the valves. Cams cannot be made steep beyond a certain limit, and so, to give the extra speed of lift, the camshaft is in this case offset ⅞in. from the valve tappets. It may not appear a very important point when first considered, but, nevertheless, it is one of those refinements that make all the difference to a racing engine. The valves, as in the motor last described, are situated in a single pocket, one over the other, but—and here we believe the engine to be quite unique—the exhaust is over the inlet, not vice versa, as is the almost universal practice. The idea the designer had in mind when he adopted this arrangement was, we believe, to allow the exhaust gases to be driven out in one upward sweep, instead of it being necessary to force them round a sharp bend. Of course, it may be argued that the incoming charge has to make the same sharp bend, but then the volume of this gas is much smaller. At any rate, the test bench has proved that an extra 3h.p. or 4h.p. can be got out of a 4in. four-cylinder engine with the exhaust valves over the inlets than is possible with the opposite arrangement on an otherwise identical engine.

Engines of "Wolseley-Siddeley."

We will now pass on to another type of engine. We have hitherto only considered examples belonging to the international racing cruiser classes where a minimum weight limit has rendered the cutting of weights unnecessary. In the unrestricted classes, however, the problem is a different one, in that it resolves itself into the extraction of the greatest possible amount of power from the least possible weight. In practice, however, the procedure in either case is the same as regards those points that have already been discussed; in the latter case there is simply the additional problem of saving weight in the fixed as well as in the moving parts. Boring out will, of course, be resorted to wherever possible, and there is little doubt that, for minimum weight, a V setting of the cylinders is best, as is found in the Antoinette engine and also on the engine of "Dixie II."

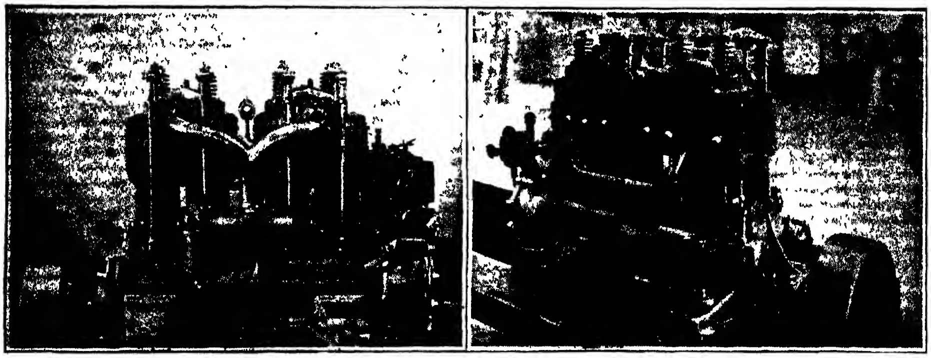


Fig. 6.—Thornycroft motor.

Before, however, considering this latter engine, the motors of "Wolseley-Siddeley" may be described. They represent the acme of reliability and give less trouble from overheating—the bane of big engines—than any with which we have had to do. To gain this end, as many as eight cylinders have been adopted for each engine, working on an eight-throw crankshaft and not on the V principle. The engines, in fact, have been primarily designed to *keep running*, and accordingly we find that the compression is not inordinately high, the valves being side by side in pockets. Weight has been cut wherever possible, and sheet-metal water jackets are employed, screwed on to the cylinder casting. Each engine develops just over 200h.p. at 1,000r.p.m., and we do not think it is any longer a breach of confidence to state that the bore is 6¼in. and the stroke only slightly greater.

It is a beautifully clean and simple design and must appeal to every engineer. The great secret of the success of these motors lies in the cooling arrangements. Water-cooled valve caps are fitted, and the main jackets, besides being extremely large, are most carefully designed, while the sparking plugs have been so placed that they get the maximum benefit of the jackets and are also in way of the cool, incoming gases. The crankcase is cooled to a great extent by the huge vent pipes, four being fitted along each side, and, in addition, the lubricating oil is cooled by being taken out of the case and carried through a longish length of exposed pipe before being delivered by the pump to the bearings. For this purpose from 6lb. to 12lb. pressure is employed, and, as may be seen from the illustration, the oil pipes are of such a size as to practically preclude any possibility of choking. The carburetter, it will be noted, is canted to compensate for the slope of the engines in the boat. We regret that we are unable to furnish any particulars of the valve setting.

Fig. 7.—One of "Wolseley-Siddeley's" engines.

The Engine of "Dixie II."

This motor is an example of weight-cutting reduced to a fine art, but the engine, besides extreme lightness, has several out-of-the-way features. The bore and stroke are each 7½in.—the stroke, we think, might with advantage have been greater—and there are eight cylinders set in a V. At 950r.p.m. about 270h.p. is developed, and at 750r.p.m., about the greatest speed at which the motor can be depended upon to run for long periods without overheating, 200h.p. is obtained. The power of this motor may, therefore, be considered the same as that of one of the Wolseley-Siddeley motors just described, but, in spite of the greater bore, the weight of the American engine must be very much less.

The V setting would, of course, account for a great deal of this, and a further reduction is effected by doing away with valve pockets and putting the valves in an inclined position in the cylinder heads. The tappet gear, too, is very light, consisting of rocker arms pivoted between each pair of valves. These rockers are actuated by tappets off a single camshaft running along the top of the crankcase between the cylinders. The exhaust valves are outside, the inlets inside, the latter being, therefore, actuated by a cam of undercut profile. Hence, there are only eight cams for the whole 16 valves. The only weakness of the arrangement lies in the fact that the inlet valve of any one cylinder cannot be opened until the exhaust is closed. Indeed, since the tappet has to drop off the exhaust cam into the inlet recess, an appreciable interval must elapse between the closing of the first and the opening of the second.

Naturally, in an engine of this size one looks for special cooling arrangements, but, as a matter of fact, nothing more than large and carefully-designed water jackets have been adopted. Auxiliary exhaust ports are provided at the bottom of the cylinder trunks, and by means of these, it is stated, 70 to 80 per cent. of the exhaust gases are discharged, thus avoiding any undue heating of the ordinary exhaust valves. It has been the experience of many experimenters that these auxiliary ports interfere

seriously with the running of motors to which they are fitted, owing to a considerable quantity of exhaust gas being sucked back at the end of the induction stroke. This difficulty has, however, been got over in the present instance by fitting mechanically-operated valves just outside these ports, so that they are only open when the piston is at the bottom of the exhaust stroke and closed at the bottom of the suction stroke. The valves are operated by an extra set of cams on the main camshaft.

All cylinders are separately cast and are provided on each side with sheet-metal jackets. The connecting rods of one set of cylinders have forked big-ends and work on the big-ends of the other set; in this connection it should be noted that both sets of rods are of the same weight, and so no balance weights are required. The upper half of the crankcase is of manganese bronze, as also is the flywheel, which is situated at the forward end of the motor, and, as will be seen from the illustration on a previous page, is of large diameter and light weight.

The water circulation deserves special notice. Knowing that water in a complicated arrangement of branch pipes does not always behave as it is expected to, the designers have avoided all possible trouble by fitting a separate plunger pump to each cylinder, driven at a quarter the engine speed. Water enters the cylinders at the base of the auxiliary exhaust valves and leaves at a point close to the inlet valves. A single carburetter supplies all the cylinders. It has, of course, been specially designed for the engine, but has no very unusual features, being of the ordinary float-feed single-jet type. There is a hand-adjusted auxiliary air valve and an adjustable needle valve for the petrol supply. Low-tension ignition is employed, and starting is effected by hand through a two-to-one chain-reduction gear.

The weak point of this engine undoubtedly lies in the cooling arrangements, and were it not for the auxiliary exhaust ports, it probably could not be kept running at all for more than 20 minutes at a time. As it is, it is possible to keep going indefinitely at 750r.p.m., but if pressed above that limit pre-ignition sets in.

Fig. 8.—A "Wolseley-Siddeley" engine, valve side.

CONSTRUCTIONAL DETAILS OF INTERNAL COMBUSTION ENGINES.

In dealing with this subject we have taken at random a make of petrol motor, and will describe some of the more important parts of the mechanism, using such description as a means of illustrating the practice in general, our object being to place such information before our readers as will enable them to form a correct opinion as to the merits of any particular piece of mechanism that they may be called upon to closely examine or criticise.

It must always be remembered that there are generally several methods of doing a certain job, and although without doubt one of these methods—all other things being equal—is the correct method, yet the alternatives will in all probability be inferior in such a slight degree that it would be quite wrong to say that they were not correct practice. We wish to be emphatic in our warning on this point, for it is so often found that a man will condemn a system or article because it differs from something which he knows from experience gives excellent results.

Again, we wish our readers to remember that two articles may be made from the same drawings, the same materials, and in the same manner, and yet one will be greatly superior to the other, not because it looks better or has more finish, but because the amount of error allowed in the manufacture is considerably less than in the other instance. This amount of error is just one of those things that cannot be located by a casual examination.

It is often thought, in manufacturing such things as piston rings, crankshaft bearings, etc., that they are simply machined to jig and gauge, and will therefore be perfectly correct. Theoretically, this should be so, but unfortunately in some operations the minimum error in machining is greater than the maximum allowable in assembling for first-class work.

In some foreign engines (not the French, however) the crankshaft and bearings are assembled direct from the machines, and, as a contrary example, we may say that in the crankshaft illustrated in this example there is about two days' expert work put in in accurately scraping the bearings to the shaft. Good machining will bring all parts into contact within, say, .002in., while good scraping will bring them within .0001in. In the former case the bearings will only be touching in a few places, and consequently the actual pressure on these points will be so high that all lubricating effect will be destroyed, and abrasion will take place, which will spread very rapidly, and after a few weeks of running the bearings will require letting together, while if they were properly fitted they would last for years.

Piston and Connecting Rod.

Let us first consider the piston and connecting rod (Fig. 1). It will be noticed that all superfluous metal in the piston has been eliminated, for the piston is reciprocating weight, and consequently its inertia throws a considerable amount of strain on the engine, and

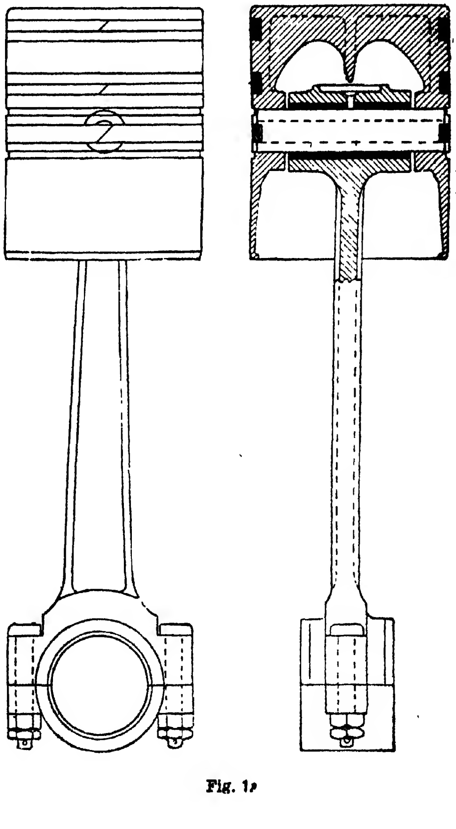


Fig. 1.

increases the pressures on the bearing surfaces. The lower part of the piston walls, which have very little work to do, are extremely thin, and are machined on the inside, while the upper part is thickened sufficiently to allow the recesses to be turned for the rings, and its strength is provided for by means of cross-webs, terminating in a point which collects and drips the oil down on to the gudgeon-pin bearing.

It will be obvious that the whole of the pressure about the piston, which in this case amounts to a little over a ton, has to be transmitted from the piston-head to the connecting rod, and it will be seen that it is necessary to make ample provision for this. Next to the strength comes the question of the proper fit of the piston. If the piston and cylinder were both at a constant temperature, this would be a very simple matter, for it would simply mean that the piston would be ground, say, .0005in. smaller than the cylinder, and no rings would be required. But as the piston has to act as a guide and receive a considerable amount of side-thrust, and as the lower part of the piston is at a temperature somewhere about 200 degrees F., and the crown of the piston is nearer 800 degrees F., it will be seen that a considerable amount of attention has to be paid to the necessary reduction in diameter to compensate for the expansion.

A common practice is to reduce the whole diameter equally, but the best method is to reduce it either step by step between the rings or to taper from the gudgeon-pin upwards, leaving an extra amount of clearance at the very end. The amount of clearance seems to vary with every engine, so that a considerable amount of actual experiment is necessary in order that the piston when working full power may be practically parallel.

Grinding.

In the case in point the dimensions would probably be from —.005 to —.012. In all good shops the whole of the turnery for working parts is finished in the grinding lathe. The piston would be finished two or three thousandths larger than its largest dimension when complete, and, of course, the ring grooves should be accurately turned to fit a gauge. It would now be put in the grinding machine, which is a form of lathe, in which the work would revolve between fixed centres at a speed of about 100 revolutions. The tool consists of an emery wheel of very fine grade, about 10in. in diameter, and revolving at some thousands of revolutions. The wheel is fed up to the piston, and then rapidly passed backwards and forwards over the work, or rather the work, which is held on a sliding table, is automatically reciprocated in the same manner as a planing machine table moves. A jet of water is directed on the surface, and the result is that, as there is practically no pressure on the work, or any strains transmitted through same, a beautiful surface can be obtained, and so accurate and fine is the machine that a parallel cut can be taken along a piston, reducing it in diameter no more than .0001in.—that is to say, one ten-thousandth part of an inch, or one-tenth the thickness of a cigarette paper.

Piston Rings.

Now we have the rings to deal with, and these are of very great importance. The rings should be turned slightly larger than the cylinder, and the bore turned eccentrically, and they should be faced on their sides so as to accurately fit the grooves in the cylinder. They should then be split at the thinnest part. The next operation is to compress the rings, so that the slot is closed, clamp them in a jig, and then grind them to a dead fit in the cylinder. If, as is sometimes the case in cheap work, they are turned a little larger than the bore, then cut across and sprung into the cylinder, the results will not be so satisfactory, as the ring will not be circular in shape when it is in position. Perhaps the best form of ring is obtained by turning the ring to fit the cylinder, placing it in a die, and hammering the inside edge. But this is a process that requires extremely skilled labour, and is not generally resorted to. These rings are known as the Davy-Robertson rings.

The illustration (Fig. 1) will show that two rings are fitted to one groove. We believe that rings fitted in this way are more satisfactory, but undoubtedly the ring that makes the best joint is made as follows :—

Two narrow, comparatively weak rings are taken and mounted over a strong ring, which forms a spring and presses them outwards, and the two rings are located or pegged on this spring, with the three joints equally divided around the circle. This ensures an excellent bearing surface, and prevents any leakage past the joints; but unfortunately this type of ring does not lend itself to motor work, as the spring cannot be sprung over the piston, and a junk-plate has to be fitted. With regard to the fit of the rings sideways, this is most important. There should be no shake whatever, and the rings should bear equally all round the groove, which is a point which is very often lost sight of in this connection.

In the illustration a ring is shown slotted into the gudgeon-pin and so holding it in place. It is an open question whether or no this be good policy, but, in high-speed engines especially, where everything has to be flooded with oil, a ring near the bottom of the piston trunk is very efficacious in preventing an excess of oil getting past the upper rings and fouling the top of the piston.

The Connecting Rod.

The connecting rod in this instance is a drop-steel forging, fitted with a phosphor-bronze bush at the small end, and the big end is machined and fitted with a brass. A gun-metal cap is then applied, and these brasses are lined with white

metal and machined. The machining operations on both big and small ends are carried out on a jig, so that both pitch and alignment are correct. If your engine does not run sweetly, and the brasses of the connecting rod wear unevenly, or the connecting rod tends to float from side to side as you turn her round by hand, you will in all probability find that your connecting rod is out of alignment.

In the illustration it will be noticed that only two bolts are utilised to hold the cap on the big end, one each side This arrangement is quite satisfactory on very small engines, but on larger ones two bolts are desirable, as prolonged use generally produces a tendency to crystallisation, so that the strength of the bolts is greatly impaired. Especially is this noticeable where there is a good deal of vibration, and on some motor-buses, where vibration is of course at its worst, a good deal of trouble has been experienced with big end bolts after a year's use.

End Bearings.

With regard to the bearings for both the large and small ends, some engineers favour white metal, while others prefer some form of bronze. Personally, we have a preference for bronze, especially where the bearing pressures are liable to be heavy, and in quick-running engines the inertia effect will sometimes produce a very high pressure per unit of surface. Undoubtedly the best practice for the small end is to provide a bronze bush that is forced in, but it is necessary that the hole in the small end should be in line, in order that when a new bush is inserted there should be no error in alignment. We again favour a round section connection rod made hollow, and provided with a bush at the small end and white metal bearings at the big end, the white metal being embedded in the steel, and not carried in a bronze shell. One of the merits possessed by the round section hollow connecting rod is that it is cheaply machined all over, and any defects there may be in the forging are thereby exposed.

Gudgeon-pin.

With regard to the gudgeon-pin, this should be of mild steel, case hardened, or nickel steel, case hardened. An important point with regard to the gudgeon-pin is the method of securing it against longitudinal motion. In this case we have one of the rings so arranged that it prevents any motion of the gudgeon-pin. This practice is open to question, as some engineers claim that the functions of the rings are annulled, and, secondly, should the connecting rod seize on the gudgeon-pin it would, without a doubt, fracture the ring. On the other hand, a ring at the bottom of the piston is very useful where there is an oil feed to the cylinder wall. Without it a good deal of oil is liable to pass the rings and cause fouling.

One of the best methods in use is to provide a circular peg, screwed at the bottom end, and with a flat milled at an angle at the side of the peg which registers with a flat milled on the gudgeon-pin. A split-pin on the end of this peg will prevent the nut coming off, and it is impossible for the peg to be withdrawn while the piston is in the cylinder. Set screws, with spot holes in the gudgeon-pin, and a spring washer or other locking device, providing the head of the set screw and *not the point* locks, are good practice, but on no account should an ordinary set screw, making contact at its point and devoid of any locking arrangement, be accepted.

With regard to the locking of the big end bolts, the best practice is undoubtedly to put on the lock-nut first (which, by the by, is the correct position for a lock-nut), and then use a full-thickness castellated nut and split-pin. A single nut with a split-pin on the top as a locking device for any moving part is of very little utility, for should the nut become loose it will in all probability sheer the split-pin. In dealing generally with this question of locking nuts we may say that a castellated nut and split-pin can always be relied upon.

The Camshaft.

Gas-engine camshafts are very substantial, and the cams are driven by means of a feather, and sometimes a key, and when motors (we use the word in the conventional sense) were first introduced they were also provided with built-up camshafts, and the cams secured with feathers, keys, or cotter-pins, though we have seen examples where the cams were held on by means of grub-screws, with spots provided on the shaft. It was quickly found that this method was unsatisfactory, and the camshafts were made from the solid (Fig. 2). The correct method is to machine a shaft from a solid piece of steel, with collars left where the cams have to be. This blank is then put in a copying machine, and the cams are milled into form, the correct setting of the cams being obtained by a dividing plate, and it is very important that the work should be done in this way, as otherwise it is extremely difficult to get a correctly-formed cam. The camshaft is then turned a few thousandths over-size, case hardened, straightened, and then ground to its dimensions, and on no account should a motor be accepted

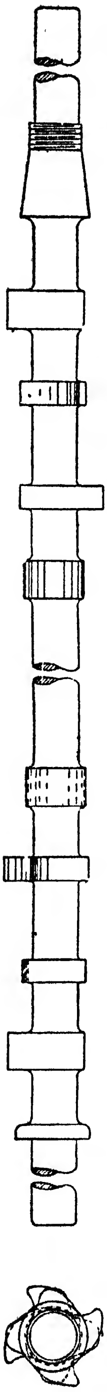


FIG. 2.

that does not possess case-hardened cams. Of course, it goes without saying that the camshaft should be supported right up to the cams by suitable bearings.

The next point is the gear wheels. They should be enclosed in the crank-case or a properly constructed gear-case, and should be cut from bronze, if they have to run on a mild steel pinion on the crankshaft. On some engines, especially where silence is a great desideratum, fibre wheels are successfully employed.

Crankshaft.

A crankshaft at one time was forged as near as possible to its shape, so as to minimise the amount of surplus metal to be removed. This was before the time of high-speed lathes and high-speed cutting tools, when the smith was a cheaper man than the machinist. Now we are afraid that the tendency is with a four-throw motor shaft to machine the shaft out of a very roughly-hewn billet of steel, and unfortunately this does not provide so good a job as a shaft that has been forged to shape, for in the latter case the fibres of the metal conform more nearly to the shape of the finished article. Then there comes the question of material. The catalogue generally describes it as the "best steel for the purpose"; but then it is very hard to say what is the best steel for the purpose, though perhaps a 3 per cent. nickel steel will be found the most satisfactory. This should give a tensile strength of about 50 tons to the square inch and an elastic limit of, say, 35 tons, and have good wearing qualities.

Theoretically, cast steel should make an excellent job, but unfortunately such a thing as a motor crankshaft cannot be turned out in cast steel and guaranteed to be a sound job. This material should be absolutely tabooed. Some foreign manufacturers save money by using steel castings, and as toys no doubt such engines are satisfactory, but for serious work they should not be considered under any pretext.

It is very seldom that any error is found in the proportions of a crankshaft, but perhaps it would be as well for us to outline the rules governing this. First of all, it will be found that if a crankshaft is made sufficiently large to offer the correct amount of bearing surface it will be found in most cases to be of sufficient proportions to successfully transmit the strains it will be called upon to do. That is, of course, providing it is of the right proportions and of correct material.

Pressure on Bearings.

The pressure per square inch of projected area of shaft bearing or crank-pin should not exceed 400lb. per square inch, and the following formula will give the diameters necessary when the length of journal does not exceed 1.5 times the diameter :—

$$d = \cdot 06\,D\,\sqrt[3]{P}$$

when d = diameter of crankshaft
D = diameter of cylinder
P = maximum pressure in lbs. in the cylinder per square inch absolute.

However, when the length of journal is greater than 1.5, the following formula should be used :—

$$d = 05\,\sqrt[3]{P\,L\,D^2}$$

when L = length of journal.

(Hyler White.)

As regards the proportions of the cranks, a single crank or multi-throw crank, with bearings between each throw, taking the diameter of the shaft as ascertained by formula, it is best to make the webs 0.8d in thickness, 1.4d in width, and an excellent proportion for the crank-pin is 2d in length and 1.2d in diameter. In a four-throw crank, if there is one middle bearing, the proportions can be increased by 10 or 15 per cent.

Unfortunately, the available width will often not allow a long crank-pin bearing, so it is increased in diameter in order to obtain the necessary surface, and crank-pins can with advantage be made hollow, for it reduces the weight of the unbalanced parts.

Practice.

In the drawing (Fig. 3) it will be seen that small or auxiliary bearings have been inserted. This is not the usual custom, but we cannot too highly commend it in all cases where space can be found for it. It will also be seen how the coupling flange is formed on the shaft, and how the spigot or clutch steady bearing is arranged and fitted with a bronze bush. These spigot bearings very often give a great deal of trouble, and it should be ascertained if adequate lubricating arrangements have been provided.

With regard to the machining of a crankshaft, they are very seldom finished in the grinding machine. If you find that they are so prepared, you may consider this as a good omen. It is not always a good sign when you see a lot of emery paper finish on the crank-webs, for there is no object in spending money in such a case in an enclosed engine, and such work may perhaps be done to detract your attention from other very serious faults.

The chief fault that is found in a crankshaft is that the crank pin is not parallel with, or not in the same plane as the axis of the shaft. To test this, put the crankshaft between the centres or on V blocks, make a light dummy connecting rod, as long as convenient; this can consist of a wooden V clamped lightly on to the crank pin, and a wooden rod projecting at right angles from same. Through the further end of the rod can be passed a lead pencil, then when the crankshaft is rotated the lead pencil will trace a pattern on a piece of paper that will tell its own tale. This error will show itself in practically the same way as does that of the connecting rod.

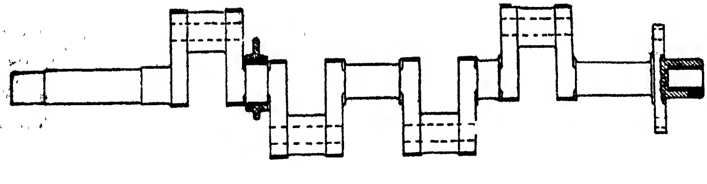


Fig. 3.

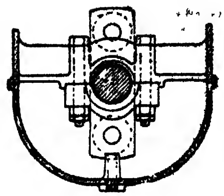


Fig. 3a.

With regard to the crankshaft bearings; Fig. 3a shows how they are held on substantial girders, and we have already said sufficient on this matter to allow us to pass the subject by, simply calling attention to the strains that have to be provided for, and the absolute necessity of having not only the crankshaft fitted accurately to the brasses, but, further than this, the brasses themselves should be accurately fitted by the same means to the casting. We think one of the quickest and best ways to ascertain the quality of the workmanship contained in a motor is to notice if the main casting has been scraped to receive the brasses. Take them out, clean them, and rub them well in position with a light smear of red lead, and you will soon see how they fit.

One word with regard to balance weights. Motorcar engines are very seldom fitted with balance weights, as they increase the weight, but they are very desirable in a marine engine, as they relieve the crankshaft of local strains between crank and crank, and in a four-crank four-stroke engine they greatly help the main bearings, especially the centre bearing.

The Crank-chamber.

With regard to the construction of the crank-chamber, in our illustration (Fig. 4) we have a crank-chamber constructed on very sound principles; albeit it does not fully illustrate all we desire, as the suspension of the engine is not shown. If, however, the reader will imagine the flanges of the lower part of the crank-chamber extended so as to form bearers to support the weight of the machine, it will enable him to get a clearer grasp of the whole subject.

As far as structural strains are concerned, we must for the moment ignore the lower part of the crank-chamber, which is simply a cover and a receptacle to hold the oil, and, as will be seen, it is fitted with a drain tube which is used to determine the maximum height of oil when filling the crank-chamber. The upper part of this crank-chamber is in the form of a box divided transversely by panels, which are fretted and form webs to support the main bearings, the camshaft bearings, and to provide a housing for the through bolts holding the lower crankshaft brasses. It will thus be seen that the strain, which is first relieved by the bottom brass, is carried to the top of this rigid box, where it is communicated to and reacts through the cylinders, and this system gives us rigidity with a minimum of weight.

End Bearings and Gear Wheels.

By referring to the end bearing (Fig. 4a), the manner in which the idle gear wheel is carried will be seen. A bronze bush is let into a boss, and through this is passed a pin turned to three diameters, which is

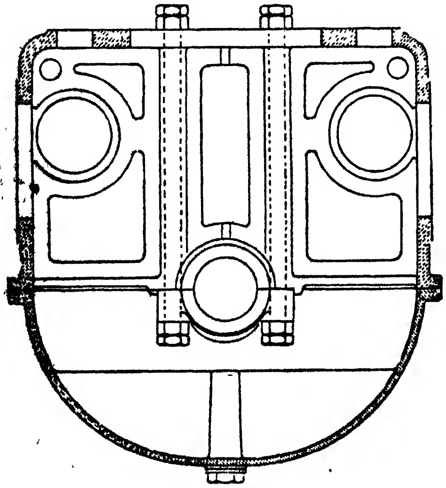


Fig. 4.

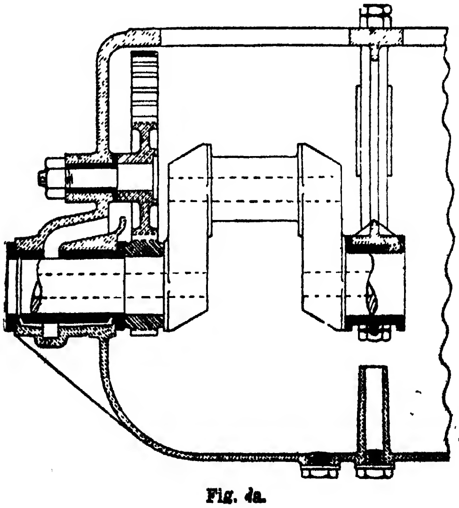


Fig. 4a.

screwed up against the first shoulder, the second shoulder serving to prevent the wheel from coming off. We refer to this point as it is in things like these where troubles arise. We know of a certain form of reversing gear where idle wheels are carried, not on securely fitted pins like this, but the pins are screwed into the casting and are held by a lock nut outside. The consequence is that if the wheel binds on the pin it tends to unscrew the same from the casting. On the other hand, we remember a pin, exactly similar to this, holding a camshaft idle wheel, coming loose during a race. It was noticed by accident, and the nut was promptly tightened up, which would have been impossible in the former instance. The figure unfortunately does not show it very clearly, but there is an arrangement for catching any oil carried outboard by the crankshaft, and returning it back to the crank-chamber; and we must again impress upon our readers the desirability of choosing a motor in which precautions of this nature have been taken. You do not want, neither can you afford, to deposit large quantities of costly lubricating oil in your vessel's bilge. Fuel is considered, but oil too often neglected.

Valve Lifter and Guide.

A very important little piece of mechanism is the valve lifter and guide, or jumper as it is sometimes termed, its functions being to convert the rotary motion of the cam to reciprocating motion. In the example (Fig. 5) it will be seen that a flanged sleeve or gland is provided, which is bolted to the crank-chamber, and which contains a turned rod forked at one end. The forked end carries a roller, which rests on the cam, and it will be seen that the side thrust occasioned by the movement of the cam is taken

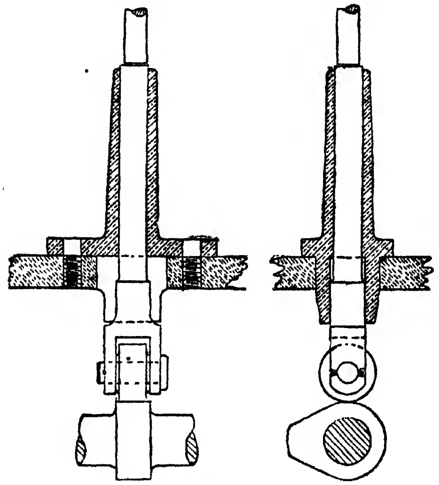


Fig. 5.

up by the guide forks. We think that there is scarcely enough guide provided in this instance. It would be better if the outside periphery of the fork were of greater diameter than the roller. The fork can then be entirely enclosed in the guide, the roller pin being made to project and to run in a groove milled in the guide, which prevents the fork turning. With this construction there are very few things that can happen that will put the motor out of action. There is, however, one exception, and it is one which should be taken seriously to heart. If sea water gets between the valve lifter and its sleeve, it will rust the former and prevent the valve from closing. Therefore, the ideal construction is to enclose the whole of the valve-lifting mechanism so that it is lubricated and protected from damp. With regard to material, the roller and pin must, of course, be case-hardened and ground; the lifter need not of necessity be case-hardened, although the end should, correctly speaking, be hardened to prevent it burring over, and so varying the lift of the valve.

Exhaust Valve and Guide.

The valve itself, together with its seat, ho[illegible]ing, and guide is of great importance. It wou[illegible] obviously be better if the exhaust valve seat could be made separately, but in the type of construction shown it is not very convenient to arrange a separate housing for the exhaust valve, although it can be readily done, as we will show for the inlet. The disadvantage of having the valve seated in the main casting, as shown, is that should the seat become worn or damaged it necessitates a new cylinder, and, further, after some years of work and a considerable amount of grinding, a standard valve will be too low, so the timing will be out, or perhaps even the valve will not seat itself, and, of course, any grinding in that has to be done must be carried out with the valve in position.

In the example shown (Fig. 6) good practice has been employed, although many engine makers contend that a separate guide is not correct. We, however, do not take this view, especially in marine engines, one point being that the guide can be made of bronze, which will prevent the valve stem from rusting up tight to a certain extent. It will be noticed that this guide is turned to fit to the hole that is bored to receive it, and is secured by a lock nut. The method of machining in such a case as this would be to bore this hole first, and rough the valve seat and bore, which latter would be finished by a cutter rotated in a jig taking the place of the valve guide.

It will be noted that there is some attempt to cool this guide by means of the water jacket, which latter we consider could have been extended with advantage, but it must be borne in mind that this water jacketing should be equal all round the guide, or it will cause unequal expansion, and the valve will not seat properly.

Timing and Valve Ports.

With regard to the timing of valves in a high-speed motor, it is necessary to give the valve a little lead, and if we have an engine with, say, a piston speed of 800ft., the exhaust

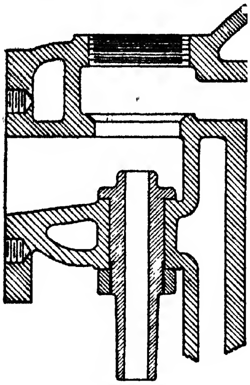


Fig. 6.

valve should open when the piston has completed 90 per cent. of its travel, and should close again a few degrees over the top centre, or say 2½ per cent. of its travel downwards, for it is obvious that during the last portion of the stroke very little work is obtained from the gases, and it allows the exhaust products to get away quickly and prevents back pressure.

Again, at the termination of the exhaust stroke, the exhaust gases will still be escaping, and their inertia will tend to further scavenge the cylinder, and allow of a quicker opening of an automatic valve, and even a scavenging effect with a mechanically-operated valve, providing this latter is on the opposite side of the cylinder. With a T-headed cylinder this phenomenon can be made to act with considerable advantage.

It is necessary that the passages and ports be made in easy curves to destroy the detrimental eddying effect as much as possible, and apropos of this we may point out that the example shown (Fig. 6) exhibits a weakness, insomuch as the valve head should be below the level of the outgoing gases, or these gases will directly impinge on the cylinder side of the valve and tend to pit it at that point. There should also be ample space round the back of the valve seat.

Inlet Valve.

We will now refer to a mechanically-operated inlet valve (Fig. 7), which may be considered as of exceptionally good design. It is self-contained in its own case, and the spring is held by a deep nut, and the split pin passes through a deep slot, thus preventing any possibility of vertical sheering strain acting on the split pin. The spring is sensitive and rapid, and is comparatively cheap to make, and it will be noticed that the stem is diminished above the thread, the object of which, though perhaps not apparent, is to relieve the weak part of the stem—that part of the thread which is just above the nut—from the tendency to elongate owing to the inertia of the valve. As it is, the stretching takes place in this weakened part, and, as there are no sharp indentations or angles, it stretches slightly without fractures.

The head of the valve is of a strong section, and yet is lightened as far as possible, and the corners round which the gases pass are rounded to destroy eddies to a great extent. It will be noted that the seats are flat and narrow, and probably for inlet valves, which are comparatively cool, better results can be obtained with this type of seat, though the common practice is to make both inlet and exhaust valves exactly alike, one reason being that the valves are then interchangeable. This, however, is another controversial subject, some authorities saying that a broad seat is necessary to prevent wear (we are referring to valve seats which are at an angle of 45 degrees), while, on the other hand, we can point to examples of engines with valves 4in. in diameter with seats only 1-16in. wide, which run year after year.

With regard to the material for valves, the seats, if separate, as per this illustration, should be made of close-grained cast iron—pot or crucible iron for preference—while the valves themselves should be made of nickel steel, either the two or three per cent. varieties, or a special brand of nickel steel containing a large quantity of nickel (about 20 per cent.). This latter material is more free from the tendency to blister or corrode, and, of course, the valve stem, spigot, and flange of the valve case should be ground to fit.

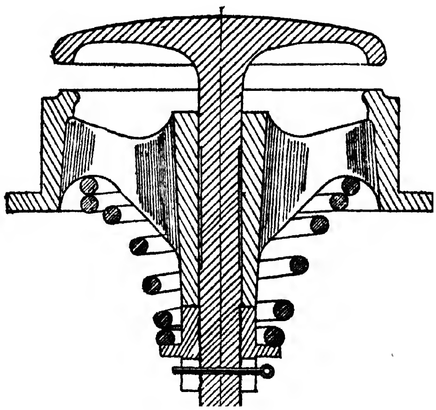


Fig. 7.

The Lift of Valves.

It will be noticed that the lift of this valve is only about ¼in., the inside diameter being 3in., thus giving a little over two square inches of area, while the total area of the valve, discounting the webs, would be about six square inches. The object of making the valve so large for this actual area is to shorten the lift, which gives us two aims, each acting in an opposite manner, the result being that a compromise has to be arrived at. First of all, we do not want to allow the gases passing through the valve to attain a velocity greater than 100ft. per second for the inlet, and 80ft. per second for the exhaust, and, in order to quickly ascertain what the correct valve area is, the formula

$$I = \frac{AS}{6000}$$

will be found suitable.

When S = piston speed in feet per minute.
A = area of the cylinder in square inches.

We give this speed of 100ft. per second as a good average, though, of course, if it can be made lower than this, it is an advantage.

Again referring to our example, it will be seen that if the lift is doubled the velocity will be decreased, but as this valve is designed for an engine running at 1,500 revolutions per minute, it will be seen that a large movement of the valve would be very unsuitable, though this does not apply so much in this case as it does in a valve that is automatically opened. In the latter case we have lift and weight tending to retard the time of opening or closing, and the strength of the spring tending to accelerate it, and again we have to find the happy medium.

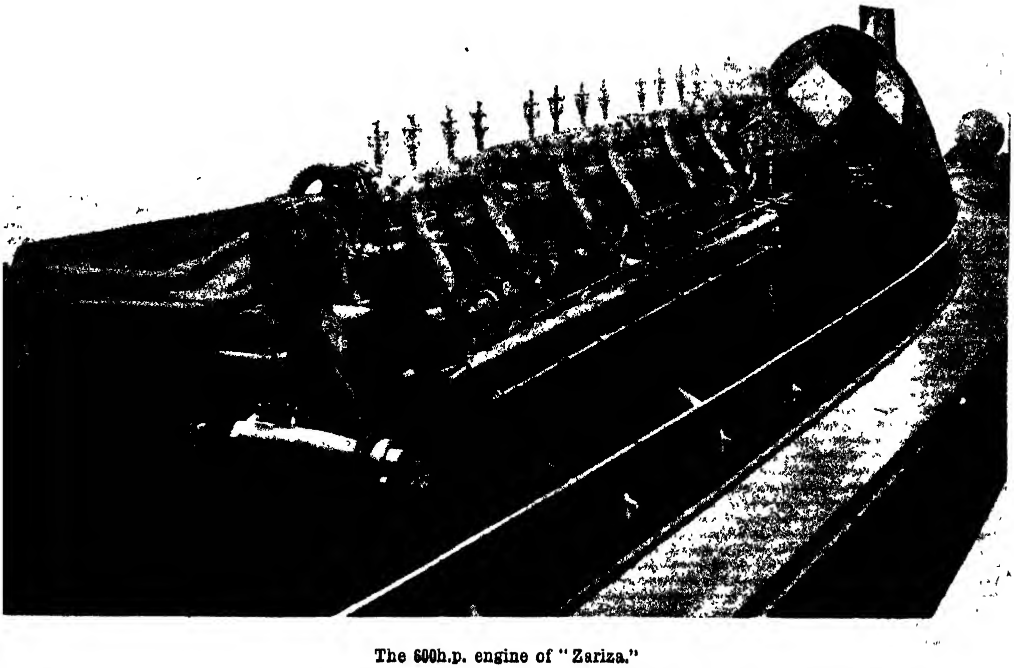
The time taken by a valve in closing may be calculated by the following formula :—

$$S = 0{\cdot}0721 \sqrt{\frac{L\ W}{M}}$$

(Hyler White.)

When S = time in seconds.
L = lift of valve in inches.
W = weight of valve.
M = average pressure exerted by the spring.

By these means any valve can easily be checked both for area and time of opening, and we think that if some of our readers interested in engines fitted with the so-called generator valves will make a few simple calculations, they will be surprised at the results.



The 600h.p. engine of "Zariza."

CARBURETTERS AND VAPORISERS.

A carburetter may be described as a device for supplying an explosive mixture of gas to the engine, and it may be conveniently considered as consisting of two parts, the first for getting the fuel into a state in which it will form a homogeneous mixture with air; that is to say, in a very finely divided or vaporous condition; while the second part is designed to carry out this mixing process.

Early types were suitable for petrol only, and the fuel was got into the form of vapour by providing a very large surface for vaporisation, either by allowing air to bubble through the petrol or by passing air over a wick or sponge soaked in the fuel. These two types were known as surface and wick carburetters respectively, but both have been abandoned in favour of the more reliable "spray" system. The reasons for this do not concern us, but in any case, the surface type is obviously unsuitable for marine work, owing to the movement of a boat, which would throw the fuel about and produce a gas of ever varying strength.

In the spray carburetter, the fuel is first atomised, not by evaporation, but by the mechanical effect of drawing it through a fine jet under the suction of the engine. Once finely divided in this way, the fuel is vaporised by contact with a fast-travelling current of air passing the jet, and that it is truly vaporised, not merely divided into small particles of liquid, is proved by the carburetter getting cold, owing to heat being abstracted by the fuel from its surroundings and disappearing in the form of latent heat of vaporisation without producing any rise of temperature in the fuel.

The spray type of carburetter has three separate parts; first, an arrangement to ensure a constant supply of fuel; secondly, a spray jet as already described; and thirdly, a mixing chamber, which will be dealt with later.

The first part takes the form of a cork or hollow metal float and a couple of levers, which, being actuated by the float as the level of the fuel rises, close the fuel supply pipe by means of a needle valve as soon as the liquid reaches a certain level, which is by far the commonest form of fuel regulator.

In the third part of a carburetter, the mixing chamber, the vapour just formed is mixed with pure air entering from a separate inlet, whence the mixture goes by way of the induction pipe system to the cylinders. In old type carburetters, the extra air inlet was hand-controlled, so that whenever the amount of gas required by the engine was varied, the air inlet had to be varied at the same time, but in the majority of cases carburetters are provided with an automatically adjusted air inlet, operated either by the suction of the engine, the exhaust pressure, which, of course, increases as the volume of gas driven out increases, or in one case by the pressure of water in the circulating system, or, commonest of all, the throttle is interconnected with a port over the air inlet, and both are operated together.

The importance of getting a correct mixture can scarcely be over-estimated; if there is an excess of fuel over air, the excess will be decomposed by the heat of the explosion, and the carbon formed will quickly soot up valves and sparking plugs, while if the mixture is too weak, that is to say, if there is more air present than is required for complete combustion, the explosions will be feeble, simply because the excess air is taking up valuable space, and does not leave enough room for a sufficient quantity of fuel to enter to produce a powerful explosion, while, in addition to this, there is considerable difficulty in igniting a charge if it be at all weak. For this reason, starting up is simplified by using rather too rich a mixture, and hence the practice of "tickling up" the carburetter to cause an excess of fuel to overflow into the mixing chamber.

If the same quantity of air were always required to give complete combustion of a given quantity of fuel, the problems of efficient carburation would be very much simplified, but, unfortunately, the volume of air required varies considerably with the temperature and with hygroscopic conditions. Hot, dry air mixes far more readily with petrol than does damp or cold air, and to compensate for the extra amount of fuel taken up on a hot day, the air inlet must be *wider open* than on a cold, damp day. For this reason an extra hand adjustment, which can be varied according to atmospheric conditions, is fitted. There are no essential differences between carburetters for land and marine use, and the various patterns are generally used indiscriminately for either class of work, though in theory the construction of the float chamber should be modified to an annular form with the spray in the centre, otherwise the rolling and pitching of a vessel will disturb the level of the fuel in the float chamber relatively to the jet; annular float chambers have in

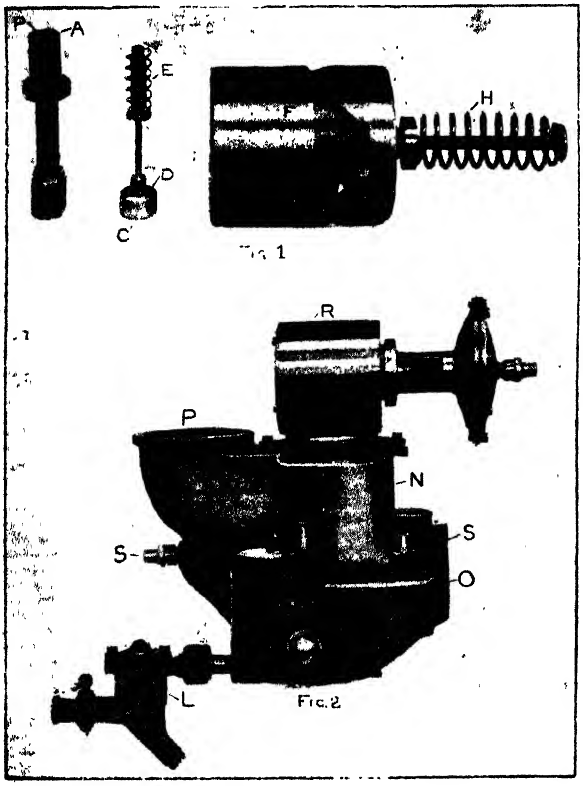
some cases been used, and in other makes the ordinary type has been duplicated, chambers being put both fore and aft of the jet, but in practice this is not found to be really essential, and perfectly satisfactory results are obtained from an ordinary car type of carburetter.

To describe all the patterns of spray carburetters is quite beyond the scope of this book, but the following examples are typical of modern practice, and they explain clearly the methods by which the principles just enunciated can be carried out. Before dealing with these, it may be as well to clear up one point about which a good deal of confusion seems to exist, even among experienced motor men. Many people talk of the fuel being carburetted by the air, but the expression is quite wrong, and it is really the air that is carburetted by the fuel, the word implying that the air is impregnated with the hydrocarbon.

Napier Carburetter for 120h.p. Engine.

One of the chief difficulties to be contended with in carburetter design is to obtain a perfectly correct mixture at all speeds. It is not too much to say that the whole behaviour of an engine, from its ease of starting to its power-developing properties at utmost speed, is primarily dependent upon the carburetter. Many an old engine we have known that ordinarily bellowed round at one speed only, any attempt at slowing down resulting in nerve-shattering bangs, frequently culminating in a fire-back that effectually deterred anyone from further efforts towards slow running. In such cases "the engine" as a whole was only too frequently condemned, but of later years it has been recognised that the remedy is to be found in the carburetter, and an all-round improvement in design has resulted in the virtual elimination of the trouble.

Of the very latest developments in this direction the new Napier carburetter fitted to the largest Napier engines of 120h.p. affords one of the most striking examples. From a personal trial we can testify to this carburetter giving a range of speed from 150 to 1,800r.p.m. without any adjustment beyond a movement of the throttle lever, all other variations of control being automatic. The carburetter is, in fact, efficient and at the same time foolproof, two conflicting qualities that are by no means easily combined.



Hydraulic regulated Napier carburetter.

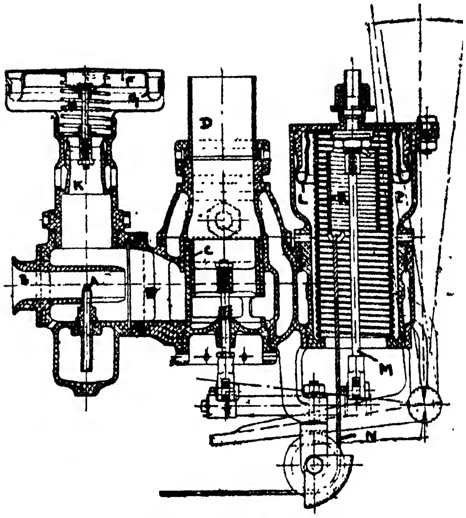
And how is this result obtained? Briefly, by means of a variable jet, the shaping of the air inlet port so that exactly the right opening is given for every position of the throttle, and the automatic adjustment of the extra air inlet to suit the engine speed. The variable jet and the main air inlet control gears are connected with the throttle lever, and are thus automatically controlled thereby, while the extra air inlet is regulated by a hydraulic throttle arranged as a by-pass of the main water circulation, so that the controlling force, or water pressure, varies with the engine speed.

As may be seen from Fig. 1, there are two outlets on the top of the jet, the first a small hole (A) known as the "pilot" jet, the other a crescent-shaped slit (B). Fitting over the jet is a cap (C), provided also with a crescent-shaped aperture (D), and held in place by a light spring (E). This cap is connected mechanically to the throttle, so that when the latter is closed only the pilot jet is open. As the throttle is opened the main jet (B) is gradually uncovered by the rotation of the cap, so that more petrol is supplied as the engine is opened up and very economical running is obtained, especially at low speed. An additional advantage is that the engine does not flood when the throttle is suddenly closed, a very common fault in large motors.

Simultaneously with the opening of the throttle and the exposure of the jet aperture air is automatically admitted, first from the main air inlet, the ports of which are cut, as already indicated, to the correct shape; and secondly from the auxiliary air inlet under hydraulic control.

The arrangement of this latter is clearly shown. F is a sleeve carrying the plunger (G), which latter is controlled by the spring (H), and opens or closes the air ports (K)—there are three of them—as it moves inside the sleeve. The necessary movement is imparted to the plunger by the diaphragm of the hydraulic throttle, and as the pressure available will evidently vary with the size and type of pump employed, the spring (H) is set to give the correct result.

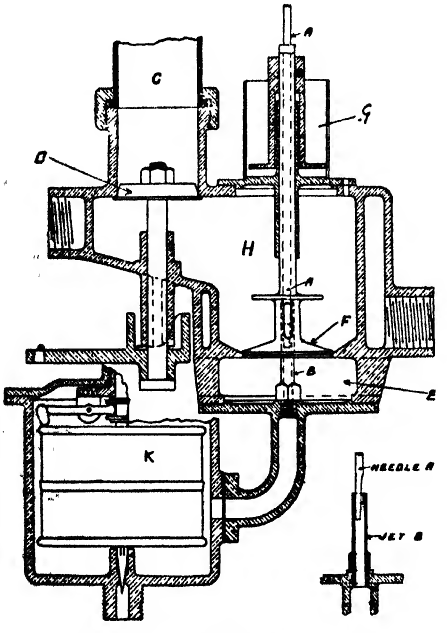
An idea of the carburetter as a whole may be gained from the illustration, Fig. 2. Here L is a petrol strainer attached to the float chamber (M), which presents no unusual features. N is the mixing chamber, O the main air inlet, and P the connection to the engine. R is the hydraulic throttle gear just described, and, finally, S S are the connections for the water jacket of the mixing chamber. Though rather difficult to describe, the carburetter is in reality extremely simple and accessible, a couple of minutes sufficing to lay bare the whole of its interior economy.



The latest Krebbs pattern.

The Brooke Carburetter.

We now come to another carburetter—the Brooke—that gives remarkably good results, and which, like the Napier, is provided with a variable jet designed to give a supply of petrol exactly suited to the requirements of the engine at all speeds. It differs from the last example, however, in that the jet is controlled by the suction of the engine, not by the mechanical action of opening and shutting the throttle. Referring to the illustration, K is an ordinary float chamber, H the mixing chamber, and C the induction pipe connection, while the throttle (D) takes the form of a mushroom valve. The orifice of the jet (B) is very large—see right-hand bottom corner of the illustration—but is partially closed by the needle (A), the end of which is tapered to a certain curve carefully calculated to give the correct orifice for all speeds of the engine. Attached to the needle (A) is an air valve (F), communicating with the main air intake (E). Now, it is evident that as the throttle (D) is opened the suction on F increases, and accordingly this disc lifts, taking the needle valve (A) with it, so admitting more air, and at the same time more petrol in correct proportion. It is easy to see that the operations of this air valve and jet regulator would be very irregular were not some means provided for damping out sudden movement, and for this purpose an oil dashpot (G) is provided. Even with this fitting it is open to question if the carburetter would prove satisfactory on a single or two-cylinder engine; probably it would not work well, and it is worthy of note that Messrs. J. W. Brooke and Co. have referred to it as a "carburetter for 25h.p. six-cylinder Brooke motor." With the steady suction of six cylinders, combined with the action of the dashpot, there would be no irregularity of movement of the valve (F), and it is easy to understand that very good results are obtained.



Brooke carburetter.

We know from experience that the carburetter gives a maximum of flexibility and an extremely rapid acceleration. Finally, it should be noted that the jet is much higher above the level of petrol in the float chamber than is usually the case.

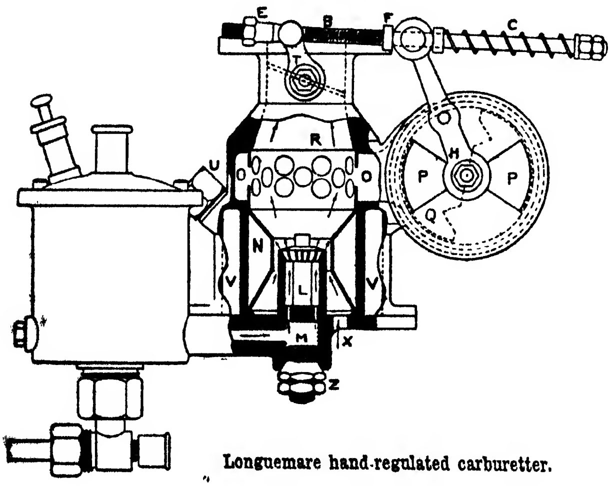
Modification of a Pioneer Type.

One of the first of the automatic carburetters placed before the public was the Krebbs, a make that has since found its place on Panhard engines. It has always been noticeable by the annular rubber ring controlling the extra air valve, but while this feature is retained there is an added hydraulic control on the latest model. In the illustration A is the jet (supplied by an ordinary float feed, not shown), B is the main air intake, and a piston throttle (C) provides communication with the induction pipe (D). Now, as this throttle is opened, it is clear that the vacuum in the mixing chamber (E) is increased, and consequently the diaphragm (F) held by the rubber mitten (G), and controlled by the spring (H), is drawn down, thus opening the extra air valve (K). There is only a small air hole in the cap over the mitten (G), so that the necessary dashpot effect is produced. The latest Krebbs model has been modified to the form shown in the illustration, but the principle just set out is to be found on all models of this make. We come now to the latest improvement, the hydraulic control, which is really nothing more or less than a governor, and which, on a car, would be controlled by an accelerator.

The arrangement consists of a mitten (L) of the same pattern as that attached to the extra air valve, but, instead of the space above it being a dashpot, it is in communication with a by-pass from the water circulation. Hence, as the speed of the engine increases, and consequently the pressure of the water, the rod (M) to which this mitten it attached is forced downwards, and through the cranks shown it operates the piston throttle (C), thus throttling down the engine. The movement of M is controlled by a spring (P), and the tension of the latter will, of course, determine the speed at which the automatic throttle or governor comes into action. To regulate the speed at which this occurs there is the spring (R) attached to the rod (M) at its upper end. The lower end of this spring is attached to a wire (N), and by pulling this it is obvious that M can be pulled down, thus nullifying the action of the spring (P) and shutting down the engine. For running at full speed R would be released, but to prevent racing in a heavy sea, or when the clutch is being taken out for coming alongside, it would be brought into action. Such a governor should be very quick-acting and a very useful fitting on certain types of boat.

The Longuemare Carburetter.

Probably the most widely used of any carburetter on the market is the Longuemare, and a description of two of the most common patterns will therefore be of very general interest, representing, respectively, hand-regulated and automatic types. We will deal with the hand-regulated pattern first. It consists of the usual float arrangement, with an easily-accessible strainer under the needle valve. The petrol flows from this chamber, the space (M) beneath the jet (L), the orifice of which takes the form of a number of jets in place of a single one. The arrangement certainly has the advantage that, to vary the size of the jet as a whole, one or more of the channels may be closed with solder, or extra ones can very easily be cut. Also, should one hole become choked, the others will still pass the fuel. On the other hand, this characteristic has its disadvantage in that the jet may become partially choked, and cause a considerable loss of power without the engineer being aware of the fact (unless he be a really first-rate man). Air enters by the inlet (X), and passes, by way of the annular space (K), through the choke tube (N) and past the jet. The space, it will be noticed, is very small, and, consequently, the velocity of the air very high, which enables it to take up the fuel as it is sprayed through the jet. No provision is made for a hot air intake, the mixing chamber being water-jacketed (V) by a by-pass from the engine. The mixture just formed passes to the mixing chamber (R), taking up extra air from the annular space (O), whence the gas passes by way of the butterfly throttle (T) to the engine.



Longuemare hand-regulated carburetter.

The extra air ports will be noticed on the right of the illustration. The

arrangement consists of a cylindrical case, with open sectors (P, P). Inside this is a sliding sleeve (Q), actuated by the arm (H), and having ports cut to the shape indicated by the dotted lines. It will be clear from the illustration that, as H is moved from left to right, the V-shaped part of the ports is first opened, admitting a little air; a continuation of the motion opens the "V" to the full extent, and afterwards the full width of the port comes into play. That is to say, the first part of the motion of H only admits a little air, afterwards a small motion produces a much larger increase in the opening of the port.

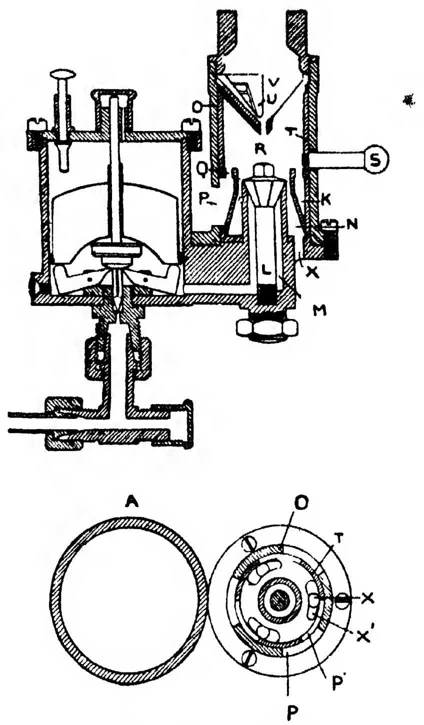
Now the throttle (T) is actuated by the rod (B), and the collar (F) will obviously open the extra air valve to a small extent as the throttle is opened, while the spring (C) closes the extra air valve as the throttle is closed. To that extent the carburetter is automatic, and can be adjusted by the screw (E) on the throttle lever; but the amount of air thus supplied is the minimum that can ever be required, and, for normal conditions, it is necessary to open the air valve against the tension of the spring (C) by means of control gear attached to H. This control is effected entirely by hand, and hence it may be said that the carburetter is of the hand-control type.

Longuemare Automatic Carburetter.

The pattern illustrated, known as Model "Y," is intended for small-power engines, and will probably be familiar to a very great many readers. The float chamber, etc., does not differ materially from the previous type. Then there is the same multiple spray jet (L), the air inlet (X), the choke tube (N), and the mixing chamber (R); further, we have extra air ports (P). But the throttle takes the form of a cone (to give the same area as the bore of the mixing chamber), and is so arranged that, as it is opened and closed, the openings of X and P are also adjusted. Reference to the illustration will make the matter clear.

The body of the carburetter (O) is joined at the top to a conical diaphragm, for reasons already stated, this diaphragm being provided with openings (V) in the form of sectors. At the bottom of the body are the extra air inlet ports (P), and the main air intakes (X). Inside the body is the cylindrical sleeve (T), which can be given a rotary movement by means of the handle (S). This sleeve carries at the top a diaphragm (U), which has three openings in the form of sectors registering with the throttle ports (V). At the lower end of the sleeve are three holes (P), registering with the extra air inlet ports (P), while the bottom of the sleeve is provided with three curved, tapered slots (X^1) registering with the main air intakes (X). The ports (Q) serve merely as a means of communication between P and the mixing chamber, and need not be further considered.

The arrangement of the ports (P, P^1 and X, X^1) can be clearly seen from the plan. Suppose the throttle to be wide open, that is to say, let S be moved as far as possible in a clockwise direction, the ports (V and U) then coincide, giving the full throttle opening, the slots (X^1) are moved so as to have their widest parts over the air ports (X), and the ports (P) are also uncovered to their fullest extent by the openings (P^1), thus giving the maximum amount of extra air.



Longuemare automatic carburetter.

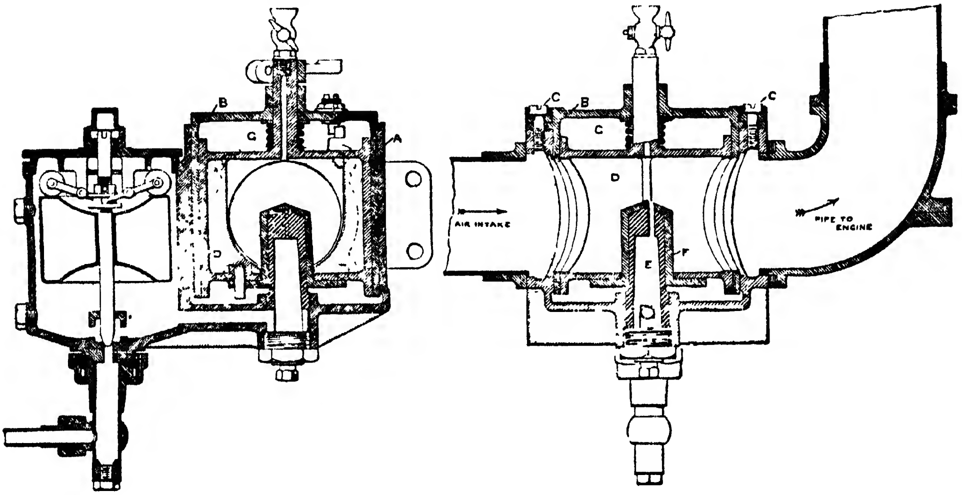
Now, as the throttle is closed, the opening of V is diminished, and, at the same time, the suction on the jet is diminished by the partial closing of the ports (X) by the narrower parts of the ports (X^1), and, simultaneously, the extra air ports (P) are partially closed by the openings (P^1). This carburetter is, therefore, perfectly automatic in its action, the movement of the throttle lever making all needful adjustments.

Carburetter for a 300h.p. Engine.

A special carburetter designed for the 300h.p. engine out of "Brooke I.," the old racing boat, is of considerable interest. It was designed during the early part of 1908 by Messrs. White and Poppe, whose standard carburetter has for some time past been remarkable for the extreme flexibility it has been possible to obtain with it. This special model, however, embodies several

improvements in detail which, we understand, will become standard in the 1909 type of carburetter. As in a previously-mentioned carburetter, the mixture is regulated entirely by variation of the jet, without any provision for an extra air valve.

The body of the carburetter (A) is cylindrical, with openings diametrically opposite each other for the air intake and induction pipe connections respectively. Inside the body is a sleeve (B), which has ports to correspond with those just mentioned, and which can be moved round inside the body for adjustment purposes, being clamped by the screws (C) in any desired position. Inside this sleeve is the throttle (D). A spindle, part of D, is brought up through the cover of the sleeve (B), and to this is attached the throttle, so that, by rotating this, the throttle is opened or closed.



W. P. carburetter for a 300h.p. motor.

We now come to the method of varying the jet. The jet proper (E) has its hole bored eccentrically, and over this fits a cap (F), with a slot corresponding with the jet. This cap is attached to the bottom of the throttle, and the spring (G), holding the latter down, keeps the cap tight on the top of the jet. As the throttle is rotated, varying the opening of the air port, the cap over the jet also rotates, and varies the size of the jet at the same time, thus giving always the correct mixture. Naturally the jet and air valves cannot be permanently set from the time of making the carburetter to give always the correct result, and it is to allow of adjustment that the sleeve (B) is provided. Suppose, for example, that the sleeve be set to give the full opening of the air port, and that the engine is found to be getting too weak a mixture, the throttle would be held full open while the clamping screws (C) were slacked off and the sleeve shifted to partially close the air port. The engine should be running all out at the time, and the sleeve would be moved to give the best result, being then clamped once more. It must, of course, be understood that the air ports and petrol jet openings have to be very carefully calculated to give the correct result at *all* speeds. That is a matter for the designer, and on it the whole success of the carburetter depends.

Before leaving this example, the float chamber should be noticed. It is of the ordinary type, but of more refined construction than is usually to be found. There is an adjustment for the length of the needle, thus altering the level of petrol in the float chamber to whatever experience shows to be best; also the tumblers on top of the float are provided with roller weights, and also have rollers to act on the collar of the needle valve, the idea being to reduce friction to the lowest possible limit.

Paraffin Carburetters and Vaporisers.

The above examples afford a very fair idea of the latest developments of carburetter design, but they have all been intended primarily for use with petrol, though many of them could be used for paraffin, with certain modifications. But we now come to the regular paraffin carburetters or vaporisers, designed expressly for the heavier fuel. In dealing with these it must be remembered that the list, as with the petrol carburetters, is representative not exhaustive; further, the types considered are only such as may be looked upon as fittings to engines, as opposed to such arrangements as are met with on special paraffin engines, the Gardner for example,

where the vaporiser is an integral part of the motor; these have already been dealt with in an earlier section.

A good deal of mystery usually surrounds paraffin vaporisers in the mind of the average man, but as a matter of fact there is nothing in their construction that cannot be easily understood. Paraffin is more difficult to atomise or vaporise than petrol, consequently, besides some form of spraying arrangement, paraffin vaporisers have additional means of getting the fuel into a sufficiently finely divided state. The heat of the exhaust gases is utilised to this end, with various modifications, and it is in the means of applying this heat that designs chiefly differ. The necessity of applying heat at starting is one of the great drawbacks to the use of paraffin to-day. Some vaporisers are heated in the first place by a lamp, others are given a preliminary dose of petrol on which the engine runs sufficiently long to heat the vaporiser, but we have yet to see the ideal carburetter that makes it possible to start up at a moment's notice from cold on paraffin as easily as can be done with petrol. When that consummation is reached, paraffin, as a fuel, will make an advance in popular favour for pleasure purposes as it has already done for commercial work.

Wolseley Vaporiser.

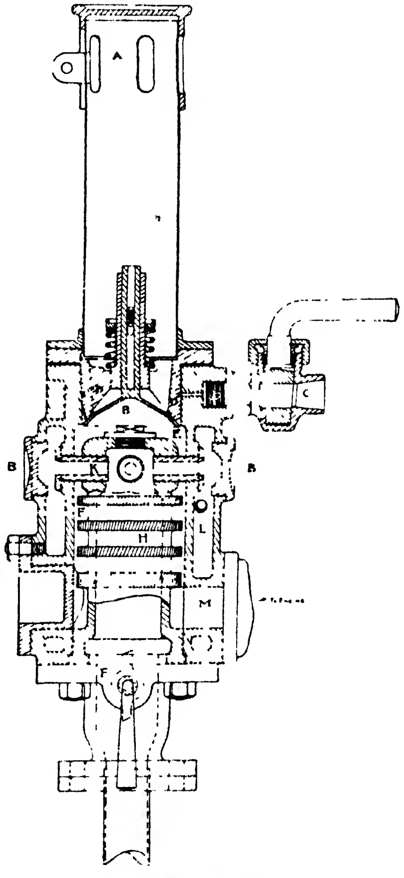
First may be noticed last year's pattern Wolseley vaporiser, which, if our memory serves, first made its appearance in its present form at the Olympia Show of 1908. At the top of a long vertical tube is the main air intake (A), a cap fitting over the ports affording a hand adjustment. The tube terminates in the body of the carburetter with an automatic valve (B) opened by the suction of the engine. Just above the valve is the fuel feed pipe (C), with a cock for adjustment purposes, and this regulates the supply of paraffin to the small annular space (D), whence it flows by small channels to the valve seating Thus the fuel is finely sprayed and carried off the valve seating by the incoming air. The mixture thus formed enters the vaporising chamber. This chamber is annular, the centre being formed by a flanged tube (H) communicating by the horizontal pipes (K), with an external jacket (L).

At the bottom of the vaporiser is an intake (F) fitted with a hand-operated valve, that communicates with the exhaust. As much of the exhaust as is necessary can therefore be passed through the central portion of the vaporiser (H), then outwards through K into the jacket (L), and thence it escapes through ports. The mixing chamber (E) has thus very great heating surface, and the mixture is brought into intimate contact with its walls, afterwards passing in a completely vaporised condition to the engine through the outlet (M).

This vaporiser it will be seen is of an extremely simple type, and is entirely hand-controlled. It has, we understand, been successfully fitted to the standard Siddeley engines, and after prolonged use the cylinders have been found quite clean, which is perhaps the best of all tests of the efficacy of a vaporiser. It will have been gathered from the description that the engine has to be started up and run on petrol for a few minutes to heat the vaporiser, or, alternatively, a Swedish lamp can be used, there being a door in the side of the vaporiser through which a flame can be played on the jacket.

An Adaptable Device.

We now come to a model that is remarkable for its flexibility and extreme simplicity, and for the fact that it can be fitted to almost any existing petrol engine with practically no alterations to the motor. It is manufactured by Messrs. Paraffin Carburetters, Ltd. The illustration shows a float feed arrangement of the usual type, but with an adjustment of the length of the needle to give whatever level of paraffin is

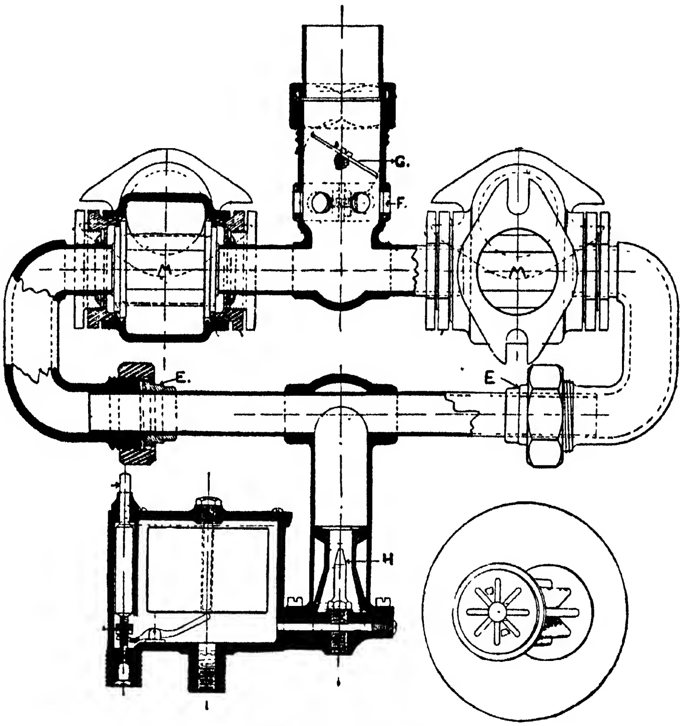


Wolseley vaporiser.

required. The jet also follows quite normal lines, but the choke tube (H) is rather small, so that the air passes the jet at exceptionally high velocity and sprays the paraffin very finely. The induction piping (C) is endless, as shown; the gas passing to either side and returning along the upper part through the vaporisers to the throttle (G).

We now come to the distinctive feature of the carburetter. A vaporiser is fixed to each exhaust port and the gas passes through these in series. As shown, the carburetter is arranged for a two-cylinder engine; for a four-cylinder motor it would only be necessary to put in extra lengths of pipe at the parts E, E, and to fit a couple of extra vaporisers in the upper part of the system. The amount of heating surface is thus varied according to the number of cylinders, so that a single design will serve for quite a range of powers. It will be understood that the mixture passing through the vaporisers is very rich. Extra air is taken up at the hand-adjusted ports (F), whence the gas passes to the engine.

The vaporiser is of extremely simple construction. It consists merely of a star-section pipe (to give great heating surface) as shown in the lower port of the illustration. This vaporiser tube has a rather restricted section, so that the speed of the gas through it is high, thus assisting the atomisation of the fuel and preventing the formation of any deposit. The tube (M) is merely placed in the exhaust pipe branch, and each vaporiser is made in the form of a compact box adaptable to almost any arrangement of exhaust ports. The heat is automatically regulated. If the engine be throttled down less gas and, consequently, less heating is required, and the heat is naturally reduced by the decreased volume of exhaust gas. The carburetter gives a great range of flexibility, and the fuel consumption is low, only .6 pint per h.p. hour. Another feature is that the float chamber and jet can be swung round to any desired position. The whole arrangement is, in fact, extremely adaptable and can be fitted to any existing engine. Unless a lamp were played on each vaporiser separately it would not be possible to start up direct on paraffin. As a matter of fact, a little petrol is always used for starting a two-way cock under the jet, enabling a change over to be made from one fuel to the other.



A paraffin vaporiser.

Westmacott Vaporiser.

Probably no vaporiser has been quite so widely used as the Westmacott, made by Messrs. Woodnutt and Co. Like those already described, it is of the exhaust-heated type and starting may be effected either on petrol or by use of a lamp. The heater takes the form of a battery of tubes, around which the exhaust gases pass, and through which the air and oil spray are drawn.

The suction stroke of motor draws air through the annular space (A), through the holes (B), lifting the conical valve (C), drawing with it a quantity of the fuel from the jet (D), which, being sprayed against the serrated conical valve (C), is atomised and thoroughly mixed with the air. This mixture is carried through the exhaust-heated tubes (E) to the chamber above, and thence to the induction pipe. On its passage through the heated tubes (E) the paraffin is vaporised. An extra automatic air inlet valve is provided at H, which opens more or less according to the speed of the motor, making a correct

mixture for complete combustion. The opening of this valve is controlled by the spring (J), the strength of which is adjusted with the nut (K).

The speed of the motor is regulated by the throttle valve (L), which closes or opens the induction pipe (G); this throttle is moved by a hand lever on the boss (M). The engine governor also acts on the throttle by a lever on the boss (N). When the throttle is moved either by hand or governor the strength of the spring (J) is correspondingly affected by the partial rotation of a quick-thread worm (O) on the throttle valve spindle moving the fulcrum of the spring lever up or down.

The exhaust gases from the motor enter the vaporiser at O, circulating outside the small tubes (E), and exit at P to silencer or overboard.

The opening at R is to apply a blow-lamp for initially heating the tubes for starting on paraffin; this opening is closed by a door when the vaporiser is sufficiently heated. When starting on petrol heating up is not necessary.

The fuel is supplied from the tank to pipe (S), and the quantity regulated by the screwed needle valve (T).

A Mechanical Vaporiser.

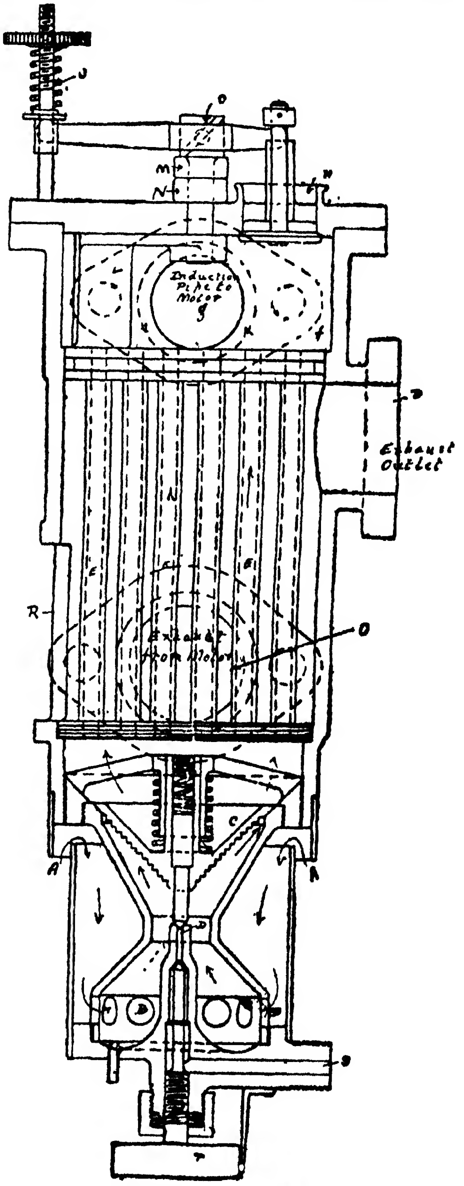
Hitherto all the vaporisers we have considered have been entirely dependent upon heat of the exhaust gases for the proper vaporisation of the fuel. We come now to a different type, the Davis paraffin carburetter, in which a mechanical mixer assists the heating arrangements in vaporisation of the fuel. The heating system, in fact, is not particularly elaborate, and the carburetter may therefore be considered a step nearer the start-from-cold ideal than are those vaporisers depending entirely upon heat.

The mechanical mixer may for all practical purposes be considered a sort of wick or surface carburetter, and for the rest there is an air valve and fuel-feed regulator, which parts may now be considered in detail.

The body of the carburetter consists of an exhaust jacketed cylindrical chamber (A), in which rotates the mechanical mixer or distributor (B), consisting of a brass frame, of which the circumference is covered with wire gauze. The spindle on which the frame is mounted can be moved horizontally, and carries (on the left) the piston air valve (C) and on the right the fuel-regulating device. This latter possesses several special features, but for the moment it will be sufficient to note that paraffin is fed through the jet (D) into the surface of the distributor.

Communication with the engine is, of course, effected through the pipe at the top of the carburetter, and it follows that air entering at C and picking up paraffin off the rapidly-revolving mixer forms a very intimate mixture, the vaporisation of which is completed by the exhaust jacket and by the three cones of gauze in the induction passage. All this gauze, it will be readily understood, offers a fair amount of resistance to the passage of the gas, and to counteract this the arms of the frame of the mixer are made in the form of a fan or propeller, as is so often done in a motorcar flywheel, thus forcing the air through the harder as the speed increases.

The mixer is rotated by a belt off the engine, and the air and paraffin feeds can be regulated either by hand (in one model) or automatically



Westmacott vaporiser.

by means of a centrifugal governor on the spindle of the mixer.

And now to the fuel pump. Paraffin enters by the connection (E) and passes to the passage (F) past the plunger valve (H). K is a small plunger pump operated by the cam (L) forcing the fuel past the non-return valve to the jet (D) already referred to.

Now, the speed of the pump obviously varies as the speed of the engine, whence the supply is very nicely graduated, but in addition a variable feed is supplied by the plunger (H) acting in conjunction with the air valve (C). The spindle of the mixer has a pointed end, and, as may be seen, this end, or cone, regulates the height of the plunger. If the engine speed increases, however, the governor moves the spindle from left to right, cutting down the air supply and at the same time cutting down the fuel feed by throttling the passage (F) with the top of the plunger (H).

In the hand-regulated type, however, the arrangement is different. A movement of the spindle from left to right opens the air ports, and also increases the fuel supply, the end of the spindle being "dovetailed," as shown, and so giving the full opening of the passage (F) when the spindle is over as far as it will go to the right. In either case, however, the effect is the same, the air and fuel supply are increased or decreased together.

Carburetters for Two-stroke Engines.

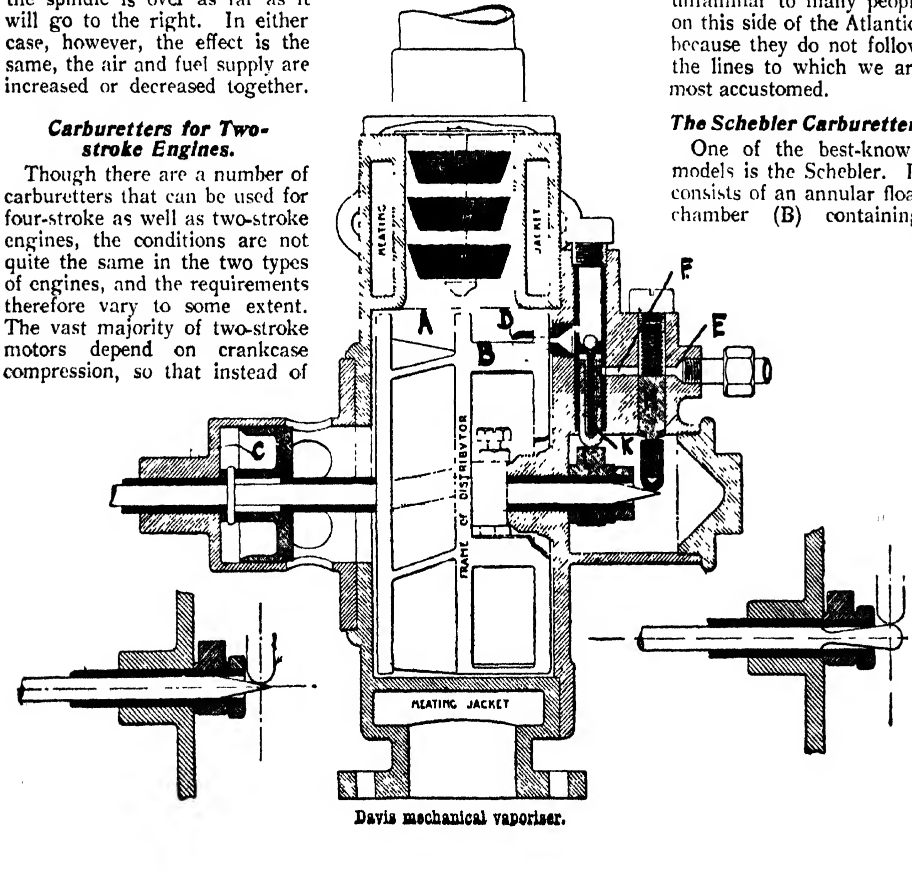
Though there are a number of carburetters that can be used for four-stroke as well as two-stroke engines, the conditions are not quite the same in the two types of engines, and the requirements therefore vary to some extent. The vast majority of two-stroke motors depend on crankcase compression, so that instead of the full suction of the cylinder, as in the four-stroke motor, a carburetter on a two-stroke engine will only be subject to the much lighter vacuum of the crankcase, in which there is very much more clearance. Further, the suction will vary considerably with different designs of engine, owing to the wide range of crankcase volume, as compared with the volume swept out by the piston, and, lastly, since the gas is churned round by the crankshaft, driven up a channel, and impinged on a baffle plate on the top of the piston as it enters the cylinder, it is obvious that it is very well mixed after it is inside the engine.

From the first two conditions it follows that in any standard type of carburetter for two-stroke work plenty of latitude for adjustment will be required, usually taking the form of a hand-adjusted jet, and from the last that the mixing chamber need not be of very elaborate design. For these reasons we have dealt with carburetters for four-stroke motors under a separate heading.

For use with two-stroke engines, American designs are most commonly employed, and extremely compact, simple, and accessible little models most of them are, though perhaps a little unfamiliar to many people on this side of the Atlantic, because they do not follow the lines to which we are most accustomed.

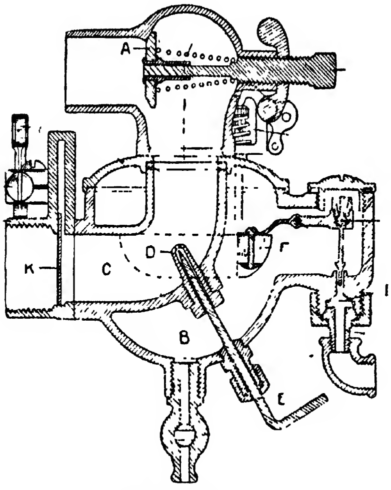
The Schebler Carburetter.

One of the best-known models is the Schebler. It consists of an annular float chamber (B) containing



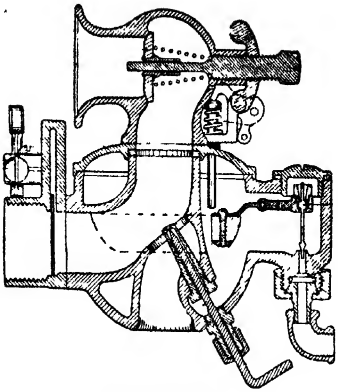
Davis mechanical vaporiser.

a varnished cork float (F) controlling the needle-valve (I) in the ordinary way. The nozzle of the jet (D) is centrally placed, but the jet is inclined as shown, and its opening is hand-controlled by the needle (E). The air intake is at the top of the carburetter, and is controlled by the automatic valve (A). The throttle (K) can be seen on the left of the illustration, and at this point, of course, is the connection to the engine. It will be noticed that the valve (A) does not completely close the air intake. The action of the carburetter is simplicity itself. When the throttle is nearly closed the suction is slight and the air valve (A) remains shut, leaving only a crescent-shaped opening, but as the throttle is opened the increased suction opens the valve and admits more air. The air, of course, passes the jet and takes up petrol, the strength of the mixture being hand-regulated to suit the requirements of each individual engine. There is also an easy adjustment for the tension of the air valve spring.



Schebler model "D."

The model just described is known as "D"; there is also an "E" model, in which the air valve completely closes the air intake at the top of the carburetter, a fixed supply being obtained from a port at the bottom of the carburetter.

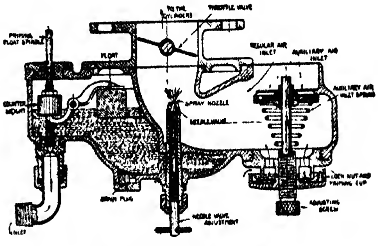


Schebler model "E."

The Holley.

Another carburetter of exactly similar type but slightly different design is the Holley, fitted notably to Fairbanks engines. Here the float chamber remains bowl-shaped, as in the Schebler, with a central jet, though the latter is vertical instead of inclined; further, the connection to the engine is on the top and the air valve at the side. As in model "D" of the type just described, there is a crescent-shaped fixed air intake, and a hand-adjusted automatic extra air valve.

There is one additional refinement that deserves notice. At the bottom of the extra air valve will be noticed some small ports, that admit a little air when the engine is running, and below which is a small priming cup. The object of the latter is to facilitate starting. A little petrol is squirted into it, and affords a rich mixture when the engine is first turned over.



The Holley carburetter.

CIRCULATING PUMPS.

The importance of the circulating pump can best be emphasised by remembering the breakdowns that so frequently occur through faults in the circulating system, and these breakdowns can generally be traced to the fact that the pump was badly designed, or was installed under conditions that were so unfavourable that it failed to accomplish its purpose.

There are several types of pumps in general use, viz., the plunger, semi-rotary, gear, and wing varieties, which may be termed positive pumps, and the centrifugal, diaphragm, and ejector pumps, which are not positive.

Plunger Pump.

The plunger, or force pump is so well known that it needs no special description. This pump is used in the engineering world for a multitude of purposes, notably as a boiler feed pump, or for any work when considerable pressure has to be overcome.

For slow-running engines this pump gives excellent results, as its piston speeds and reversals are slow, and the inertia of the moving column of water has no ill effect, but for a fast-running engine it is most unsuitable owing to the fact that the movement of the water, an incompressible medium, is arrested twice each revolution throughout the whole length of the circulating system. This produces "water hammer," which causes joints to leak, pipes to fracture, valves to wear out, and packing to give way, and a reciprocating plunger pump should not, therefore, be used for a greater speed than 60ft. per minute.

(We may mention that water hammer through excessive pump speed can be eliminated by arranging a snifting valve leading into the pump between the valves, which can be set to allow a small quantity of air to be drawn in at each stroke, which air will act as a buffer throughout the system).

If a plunger pump is used the valves must be of ample size, the packing gland substantial and well fitted, and the pump must be in every way accessible. The body should be made of gunmetal, the valves of hard bronze, and the plunger of red phosphor bronze or some such similar metal, and for sea-water work no steel should be used in its construction.

Semi-rotary Pumps.

A development of the plunger, viz., the semi-rotary pump, is a distinct improvement on its prototype for all-round motor work. It will be seen (Fig. 1) that there is an oscillating diaphragm arranged in a drum, which drum is further provided with two fixed diaphragms containing valves. The movable diaphragm, which reciprocates circumferentially on a centre common with the drum, acts as the piston of a common lift pump, working alternately on each side.

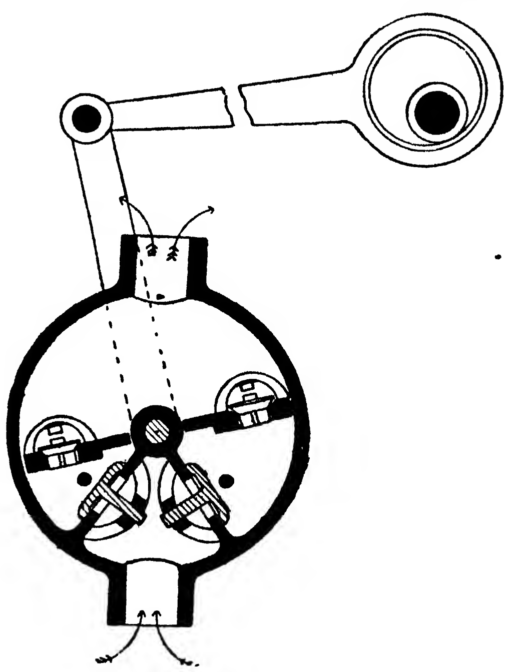


Fig. 1.—Semi-rotary pump.

It will be noted that it is reciprocated by means of an eccentric situated on the crank or camshaft, and providing this pump does not run at a greater speed than 350 revolutions of the eccentric it gives very fair results.

Its drawbacks are that wear takes place between the diaphragm and the drum, and sand or mud are very detrimental to its action. These pumps are generally made with flap valves, but those shown are preferable, for a very small obstruction near the hinge of the flap valve will put it out of action.

Incidentally it may be mentioned that if this class of pump is used for the bilge, special care must be taken to provide an adequate strainer, and the pump should be entirely of gun-metal.

These pumps, when worked by hand, are very serviceable for pumping lubricating oil, paraffin, and petrol, or for draining engine trays.

Gear-wheel Pumps.

The gear-wheel pump is perhaps the most popular one now in use; it works on the principle of the displacement of gears meshing into each

Fig. 2.—Gear-wheel pump.

other, and the accompanying illustration (Fig. 2) will show how one tooth acts as a piston and displaces the water contained between the two opposite teeth of the other wheel, which water has been brought round to the outlet side by the motion of the gears within the case, which they accurately fit.

The charm of the type lies in its simplicity, for there are no valves to get out of order, and only a simple packing to attend to, and that on a rotating shaft. Gear-wheel pumps will deal with sandy water, and will last a considerable time if properly made of correct materials. The lines shown on the ends of the teeth, which are also extended along the edges, are grooves, which serve the purpose of water packing.

These pumps will draw water some few feet when they are new, but after they are worn they need priming, and the handiest method of doing so is to arrange a grease cup so that grease can be forced into the interior, which acts as a packing until the pump is drowned.

Unfortunately a good many of this type have been placed on the market with gears so badly cut, and fitted in such a slovenly manner, that they make a considerable amount of noise and sometimes seize up, and a pump of this class which makes sufficient noise to be distinctly heard should be rejected.

The gear-wheel pump will be recognised by many as a development of the "Roots' Blower" so extensively used for foundry work and gas pumping.

Drum Pump.

Next in popularity is, perhaps, the wing, or drum pump (Fig. 3), and which consists of a cylinder containing a rotating drum placed eccentrically with the cylinder, and with its periphery in contact with the cylinder at one point. This drum contains a slot in the same plane as its axis, which slot has two tongues or wings fitted in it, which are forced outwards by a spring. It will be seen that as the drum rotates each wing alternately forms a piston, which draws in a certain quantity of water on one side, and delivers another body of water on the other side.

The drawback to the pump is that it can easily be put out of action by grit. Grit entering the pump will be forced into the point where the drum comes in contact with the cylinder, and will cause wear, and the same agent will tend to cause the wings to be arrested in their slot. A good strainer must therefore be fitted.

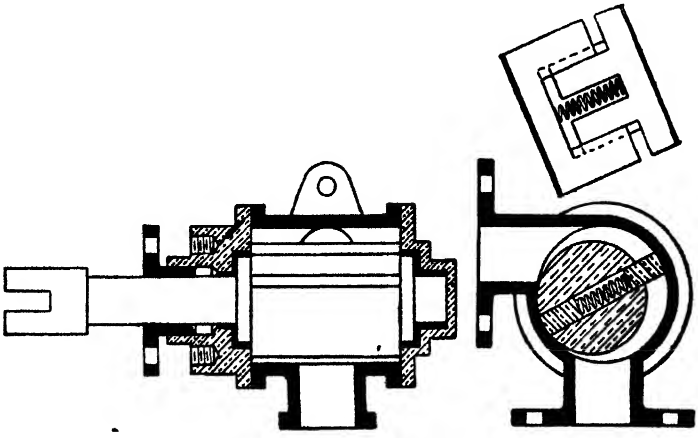


Fig. 3.—Drum or wing pump.

Taken on the whole these pumps are very satisfactory. They are about as efficient as the

gear pump, though perhaps more liable to derangement.

We illustrate (Fig. 4) another method of carrying out the same principle, in which it will be

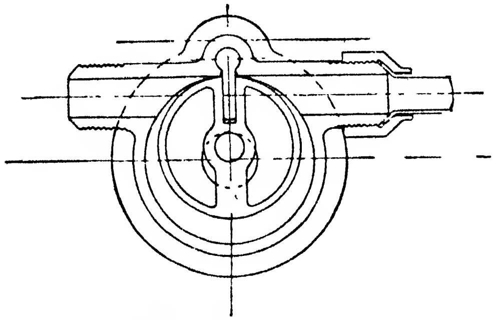


Fig. 4.—Vane drum pump.

seen that a vane is hinged in the cylinder wall and works in a slot in the drum, which latter is mounted on a crank pin formed on a shaft, whose axis coincides with that of the cylinder.

In this pump the advantage is that there is very little sliding friction on the walls of the cylinder, although it is more sensitive to obstructions than the other form.

Centrifugal Pump.

The most popular of the non-positive pumps is the centrifugal, and this is made in a variety

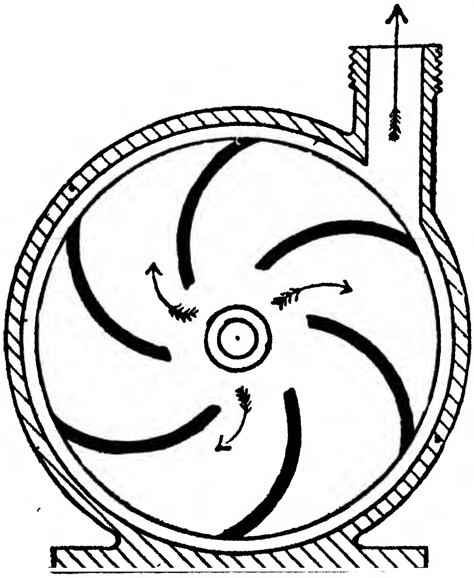


Fig. 5.—Centrifugal pump.

of forms, but a reference to the diagram (Fig. 5) will be sufficient to illustrate the general principle of the pump, whatever special form or shape may have been adopted.

In this case the vanes are cast in one piece, with a disc that should be also in one piece with the spindle, and should be made of gun-metal or bronze.

This spindle passes through a long bearing and gland formed in the body of the pump, and the body should be fitted with a door large enough for the disc to be withdrawn, which door will be provided at its centre with a connection for the inlet of water.

It will be readily seen that when the disc is revolved the water tends to pass outwards in a tangential direction, and escapes through the outlet pipe as shown. In a correctly formed pump the case is swelled gradually from the outlet, so that each blade is displacing water during every part of the revolution.

This class of pump of course has not the power of the former types, and any obstruction on the suction or delivery side will prevent the circulation of water. Again, the pump must be "drowned," it will even refuse to work when three-quarters full of water, and of course it

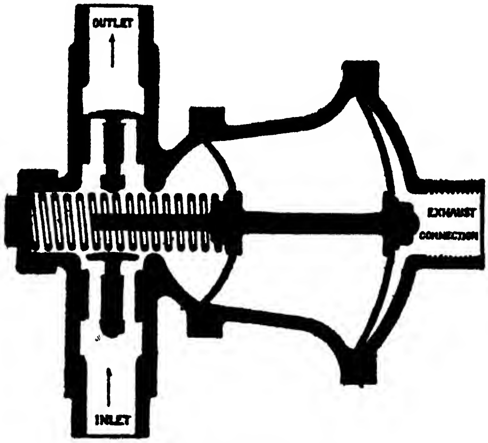


Fig. 6.—Diaphragm pump.

must be driven at a considerable speed. This speed generally necessitates driving by means of a chain or gears, and in this case it is best to mount the gear or chain wheel so that it runs on the outside of the spindle bearing, and drives the spindle itself by means of a flexible dog coupling. This relieves the spindle from any undue strain, and is the most approved method of driving.

Another disadvantage of the centrifugal type is that the pump does not hold up the water when it has stopped, and a check valve is generally placed on the delivery for this purpose, otherwise the water would drain out from pipes and engine jacket.

The pump is light, simple, and has no valves, and will be found very satisfactory if properly constructed and installed, and used in conjunction with a high-speed, high-powered engine requiring a large volume of water.

Diaphragm Pump.

In order to obviate the difficulties and troubles arising out of a packed plunger, and to eliminate the gearing required for driving, the pulsations of the exhaust in the case of a four-stroke engine, or of the crank-chamber gases when used in connection with a two-stroke engine, have been utilised to vibrate a diaphragm which acts on a suction and delivery valve in a manner precisely similar to that of an ordinary plunger pump.

In the type illustrated (Fig. 6) there are two diaphragms rigidly connected, the pulsations of the exhaust (or other) gas pressure acting upon one side of the larger one being communicated to the water upon the other side of the smaller.

It is probable that the rapid pulsations of the diaphragms would lead to fracture at the points of attachment to the spindle in course of time, but the diaphragms are easily replaced, and are not expensive. Provision would need to be made against the risk of rupture of the large diaphragm in the event of an explosion in the exhaust.

The pulsations of the exhaust were used for this purpose in one of the earliest marine engines, but the fact that so small a difference of pressure was available made them extremely sensitive, and they did not become popular, no doubt through this cause.

The Circulating Water Inlet.

However good the pump may be, should the suction become blocked by a piece of waste, seaweed, or jelly fish, the circulation will be stopped, and to obviate this every boat should be fitted with a large rose on the outside of the hull, but even then if this rose is not in a position to keep the inlet clear it will become blocked up if the boat takes the mud.

The best practice is to provide a sort of trap, a form of which is illustrated herewith. It will be seen that the water enters the trap, which should be made of sheet brass, direct into a tube of strong coarse wire gauze, which tube should be reinforced by light brass rods. There should be no strainer fitted on the outside, the reason for which will be shown. The water passes through the gauze cylinder and finds its level in the reservoir, from which it is drawn in the usual manner by the circulating pump. The utility of this will be seen by supposing a piece of waste to have wedged itself tightly in the inlet. The bayonet jointed cover would be removed, a rod passed down the tube, and the obstruction forced out. Should it be necessary to run the engine for a short time when the boat is out of the water, the pump can be supplied by water poured from a bucket into the reservoir.

A modification of this trap is sometimes used on fast launches; it consists of providing a reservoir with a scoop self-contained with the bottom of the tank, which scoop is easily accessible when the lid is taken off. A vertical gauze partition is provided, and the water passes to the pump from the other side of this partition. An overflow pipe is led from a position near the top of the tank, the scoop causes the water to rise above its normal level, and

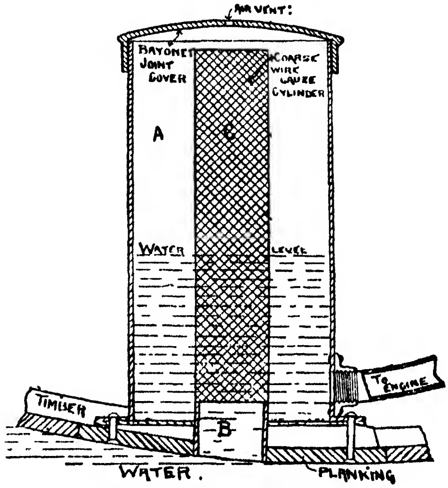


Fig. 7.—Water inlet trap.

there is always a considerable amount of circulation taking place when the boat is moving through the water. Any weeds that may be drawn in will flow out again by the overflow pipe. However, should the apparatus become choked, which will be indicated by the absence of water from the overflow pipe, the lid can be taken off and the obstruction cleared away by hand without loss of time.

A most important point is that all water-circulation pipes must be of solid drawn copper, thoroughly annealed after bending, and joints must be brazed and not soldered. In fact, the piping should be carried out as if it were for 60lb. steam service.

SILENCERS.

The whole aspect of the silencing question has undergone a considerable change of late. In the early days of marine motoring, when the influence of car practice was more strongly felt than it is to-day, the tendency was to adopt, frankly, a car type of silencer, which, to a certain extent, must be considered a compromise between noise and back pressure. But it has gradually been realised that the unlimited amount of water available in boat work can be utilised to eliminate, or, at any rate, very greatly reduce, noise, without any corresponding back pressure.

Water-cooled silencers represent the first move in this direction; then followed systems of exhausting below the water line, and, finally, there is the method, becoming every day more popular, of putting all water direct into the exhaust pipe and keeping the outlet above water level.

Silencers devoid of any water-cooling system are to-day very rarely met with, except in the form of funnels, and the systems may be classified as follow:—

1. Funnel exhausts.
2. Water-cooled silencers.
3. Partial silencers or receivers depending partly for silence on water spray or under-water exhaust.
4. Flooded exhaust pipes.

We will deal with these in order.

Funnel Exhausts.

In favour of the funnel exhaust must certainly be mentioned its low cost. It can be of the ordinary motorcar type and may be simply fixed directly over the motor, connection with which is effected by plain asbestos lagged pipe.

At one time, when the public had not got used to the look of a launch without a funnel, the type was very popular, but the reason for its adoption was as illogical as a dummy horse would be in front of a motorcar, and it is not now very frequently met with.

We do not advocate its use on small boats, for, to mention two objections, passengers are liable to burn their hands on it, even if it be water cooled, and there is always a tendency for those in the after cockpit to get a good deal of objectionable smell and perhaps a little smoke as well if the lubrication or carburation be not perfect. For cabin cruisers, however, where the funnel can be made more elaborate, these objections disappear, and there are certainly advantages, unless means of heating in cold weather be absent, in keeping the exhaust altogether out of the cabins.

Water-cooled Silencers.

Of water-cooled silencers there are a great variety, the patterns being in nearly all cases variants of the car silencer, but less elaborate by reason of the quieting effect of the water jacket. The ordinary concentric tube arrangement is very common, and is too well known to need explanation.

A very simple, cheap, and, at the same time, efficient, form is the Parsons silencer (Fig. 2), which consists merely of a jacketed cylinder and two lengths of perforated tube inside. In the illustration we will assume that the right-hand end is connected to the engine, the other being the outlet. The exhaust enters the central pipe, expands through numerous holes into the big cylindrical chamber, and is then cooled partly by its own expansion and partly by contact with the water-cooled periphery of the chamber. With the kick, so to speak, thus taken out of them, and much reduced in volume, the gases then escape by the left-hand tube, which they enter through perforations as indicated. It will be noticed that the two tubes are spigoted together in the centre, a closed cylinder or plug in one, the same plug fitting the end of the other tube and forming an expansion joint.

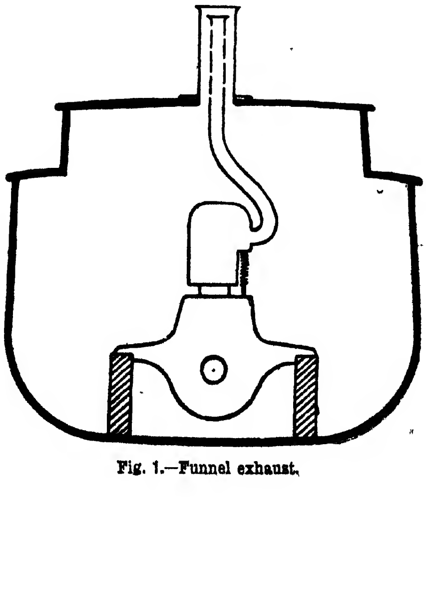


Fig. 1.—Funnel exhaust.

Fig. 3 illustrates the Universal silencer.

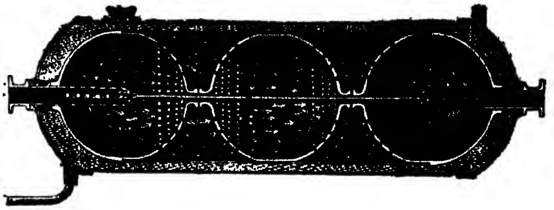


Fig. 3.—The Universal silencer.

It will be seen that it consists of three globular chambers connected by a cylindrical water-cooled casing. The exhaust pipe from the engine enters the first globe on the left, where the gases expand and leave the globe by holes in its right-hand end, entering the cylindrical chamber and being cooled to some extent by contact with its walls. The gas then passes through two more chambers in the same way, and, it is not difficult to understand, comes out very effectively silenced. To further assist in this direction, the body of the silencer has fine perforations through which fine sprays of water enter, and, being converted into steam, pass out through the ordinary outlet. It might be thought that, on this account, the silencer properly belongs to Class 3, but as it is an effective silencer independently of the water spray we have preferred to include it in the second class. Obviously, it could not be employed as a funnel silencer if the water sprays were used, as water would get back to the valves and cylinders.

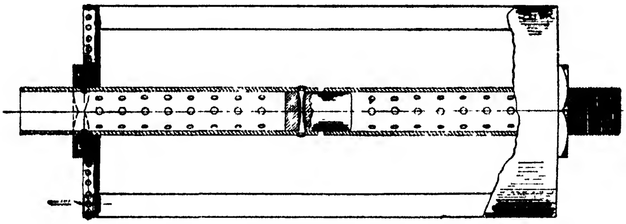


Fig. 2.—Parsons water-cooled silencer.

Partial Silencers.

This class, as already explained, includes, really, expansion boxes, usually water-jacketed, and provided in addition with water sprays in one form or another. A very simple form, tried early in the 1908 season by Messrs. Hart-Harden, is illustrated in Fig. 5. It consists merely of a deep, narrow receiver alongside the motor, the exhaust entering near the top and leaving a few inches above the bottom. All the circulating water is sprayed in at the top, and at once effectively cools the exhaust. Part of the water is, of course, converted into steam, but the remainder collects in the bottom of the receiver and drains away through the outlet, which may be taken direct through the side of the boat, making a very light and compact job. An additional advantage of the system is that it is quite impossible for any water to get to the valves.

A variation of the system was to be found on the Dixon-Hutchinson boats "Lotus" and "Lotus II." Here the receiver consisted simply of a drum with a perforated pipe running through the middle. The circulating water was passed into this pipe, and, being sprayed among the exhaust gases, cooled them very thoroughly and made it possible to take only a short length of pipe straight through the side of the boat.

A very simple variant of the principle is to be found in the Rankin Kennedy exhaust ejecter.

It will be seen (Fig. 4) that the exhaust leaving the engine expands first of all in a conical chamber, which is placed as near the engine as possible. Around the apex of this chamber is a water-jacket (C) which, through a narrow annular space, is in connection with the conical chamber. Owing to the ejector action set up, the escaping exhaust draws water from the annular chamber, as indicated by the arrows, in the form of spray, and, being considerably cooled, passes on into the exhaust receiver (B) and thence away by the pipe (O).

This is but a modification of the original system adopted in the American two-stroke engines, where a small pipe is led from the jacket into the exhaust pipe facing away from the cylinder. The principle and action are the same, but in the case we describe and illustrate, it has been perfected, and the system can be followed with advantage, although there is a possibility, when used in conjunction with four-stroke engines and when situated close to the engine, of the water being drawn into the cylinder in the case of a misfire.

Flooded Exhaust Pipes.

We may now pass on to Class 4, where silencers are entirely absent, and the reduction in noise is effected wholly by turning the circulating water into the exhaust pipe.

This system, it should be noted, does not effectively silence very slow-running engines,

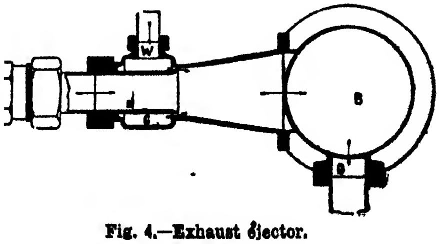


Fig. 4.—Exhaust Ejector.

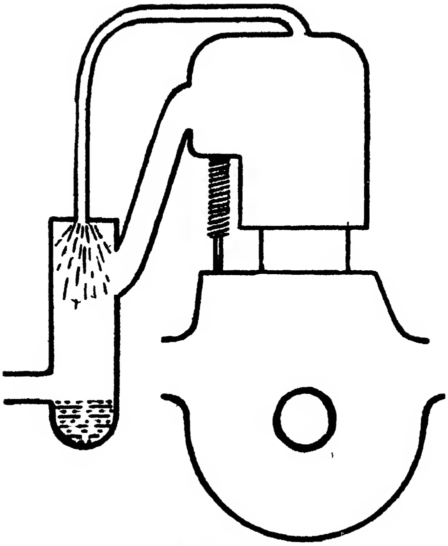


Fig. 5—A simple arrangement.

especially if they be of the single or two-cylinder type; here we have a series of "puffs," which the water does not greatly influence. But the case of moderate-speed and fast-running motors is different. Here the mere injection of water into the exhaust pipe produces a really surprising degree of silence, providing the length of pipe be sufficient, not less than 15ft. or so, and the more the better. The bore of the pipe must not be at all restricted, and it may be led straight aft. Many builders and others used to argue that this system involved great danger of getting water back into the engine, but, provided the installation be intelligently carried out, we do not think there is any danger of this.

The arrangement is illustrated in Fig. 6. The exhaust ports are connected direct to a common exhaust pipe, which should be water-jacketed on general principles of safety and comfort, not in any connection with the efficacy of the silencing. Just aft of the engine the pipe should be given a sudden drop, and should then be led straight aft with a gentle downward slope all the way, the greatest care being taken to avoid U bends on any pretext. The circulating water should be led from the cylinders to the exhaust pipe, entering just at the bottom of the bend. In all cases where there are less than four cylinders, the outlet should be above water, otherwise a sort of "water hammer" effect may be produced, and even with four or more cylinders the outlet should be above water in all cases where the ratio of power to weight is at all high, as in ordinary launches. In cabin cruisers, however, there is no objection to exhausting below water, though, wherever this is done, it is advisable to fit a length of vertical pipe to the exhaust near the engine and reaching well above the water line. A stop valve should be fitted at the top of this pipe, and it should be opened just before shutting down, otherwise there is the danger, as the gases in the engine and exhaust pipe cool, of water sucking back to the cylinders. "Wolseley-Siddeley" affords an excellent example of how efficiently a boat can be silenced by the simple expedient of turning water into the exhaust. Her two engines, aggregating 400h.p., exhausted into a common pipe, which was supplied with the circulating water and branched again to two outlets aft. The pipe cannot have been more than 25ft. long, yet the noise of the exhaust was scarcely noticeable; it was, in fact, so slight that it was possible to make the crew hear by hailing, even when travelling fast.

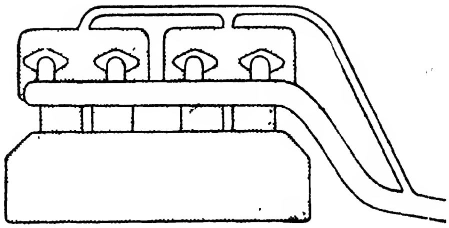


Fig 6.—The flooded pipe system.

REVERSING SYSTEMS.

Broadly speaking, the methods of driving a motor astern may be divided into three heads :—

1. A reversing engine.

2. A reversing gear, that is to say, a mechanical means of reversing the direction of running of the tailshaft while the engine continues to run in one direction.

3. A reversible-bladed propeller.

Several successful attempts have been made to produce a reversing four-stroke engine. The essential principle, of course, is to alter the valve setting to enable the engine to run the other way. This has been done, notably in one or two German and Swedish motors and also the Antoinette engine, which, having automatic inlet valves, makes it only necessary to retard the exhaust camshaft 90° and simultaneously to advance the ignition 90°. Again, in engines where the fuel feed is entirely separate from the air supply, it is possible to reverse the running of an engine without altering the valve setting at all, though the power running backwards will not, of course, be so great as when going ahead, as will be readily understood from a study of the valve-setting diagram. In this case, what was formerly the inlet simply acts as the exhaust, and vice versa, and anyone who has had to do with stationary engines of the Hornsby horizontal type will know that in starting up these motors by hand it is quite common by unskilful management to get them going in the wrong direction. It may, therefore, be said that four-stroke engines can be made reversible, but the reason why they are not more frequently so made is that they cannot be relied upon to be self-starting in a new direction. The Antoinette engine occurs to us as one that can be reversed on the switch with a fair amount of certainty, provided it be perfectly tuned up and handled by an experienced mechanic, but, generally speaking, engines cannot be relied upon to start on the switch, and either hand or compressed-air starting must be resorted to.

Two-stroke engines are, of course, capable of running equally well in either direction, and by suitably arranging the ignition gear they can be reversed by running them dead slow and then suddenly advancing the ignition, so that a backfire is produced and the engine starts up in the other direction. Here again, however, a considerable amount of skill is generally required, and very few engines can be said to be quite certain of starting on the switch. An engine that behaves extremely well in this connection is the Boulton and Paul single-cylinder, two-stroke motor, which has a specially-arranged ignition lever that makes it possible to reverse the engine without previous practice, as we have ourselves verified.

But motors cannot at present be considered easily and certainly reversible, and as trouble will almost certainly be experienced with the flurried handling that might very probably occur in an emergency when a reverse was most required, a reversing gear may be considered preferable at present for the use of the average man.

Reversing Gears.

Reversing gears may be divided into two classes: the positive type and what may be called a clutch type, which depends upon part of its mechanism being held fast by a clutch for going astern.

We will first consider the positive type. The diagram (Fig. 1) makes the general principle clear: A is a pinion on the engine shaft meshing with a spur wheel (B) on a countershaft, which shaft carries another pinion (C) (shown dotted) meshing with a spur wheel (D) on a third or layshaft, this latter wheel also meshing with a pinion (E) on the tailshaft. If this train of gears be followed out, it will be found that E is driven in the reverse direction to A. The gears are, of course, slid in and out of mesh exactly as is done with a car change-speed gearbox. An alternative method of obtaining a positive reverse is to drive the countershaft by a chain off the engine shaft and to have a gear drive from the countershaft to the tailshaft,

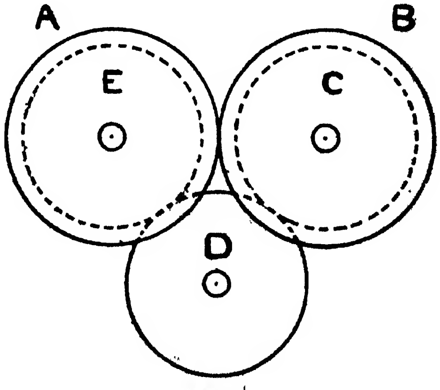


Fig. 1.

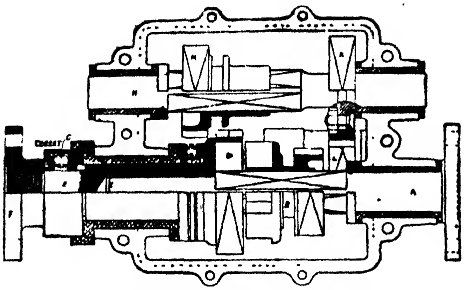


Fig. 2.—Brooke reverse gear.

which, of course, gives a reverse without the intervention of a layshaft. We will now consider some practical examples of the type :—

The Brooke Gear.

This gear is illustrated in Fig. 2. The engine shaft (A) is spigoted into the tailshaft (E). A spur wheel (B) is carried on a squared portion of the shaft (A) and carries also the jaw clutch, the whole of B being free to slide on the shaft and under control of the reversing lever. On the shaft (E) is a spur wheel (I) carrying also a jaw clutch. To give an ahead drive, B is moved aft till the jaws of the dog clutch engage, so that a clean through drive is obtained.

For the reverse the countershaft (H) comes into play; a squared portion of this shaft carries a pinion (M), and keyed to the shaft is the spur wheel (K), which is always in mesh with a pinion (L) on a layshaft underneath the engine shaft. To put the reverse into operation the pinion (B) is moved forward, that is, from left to right in

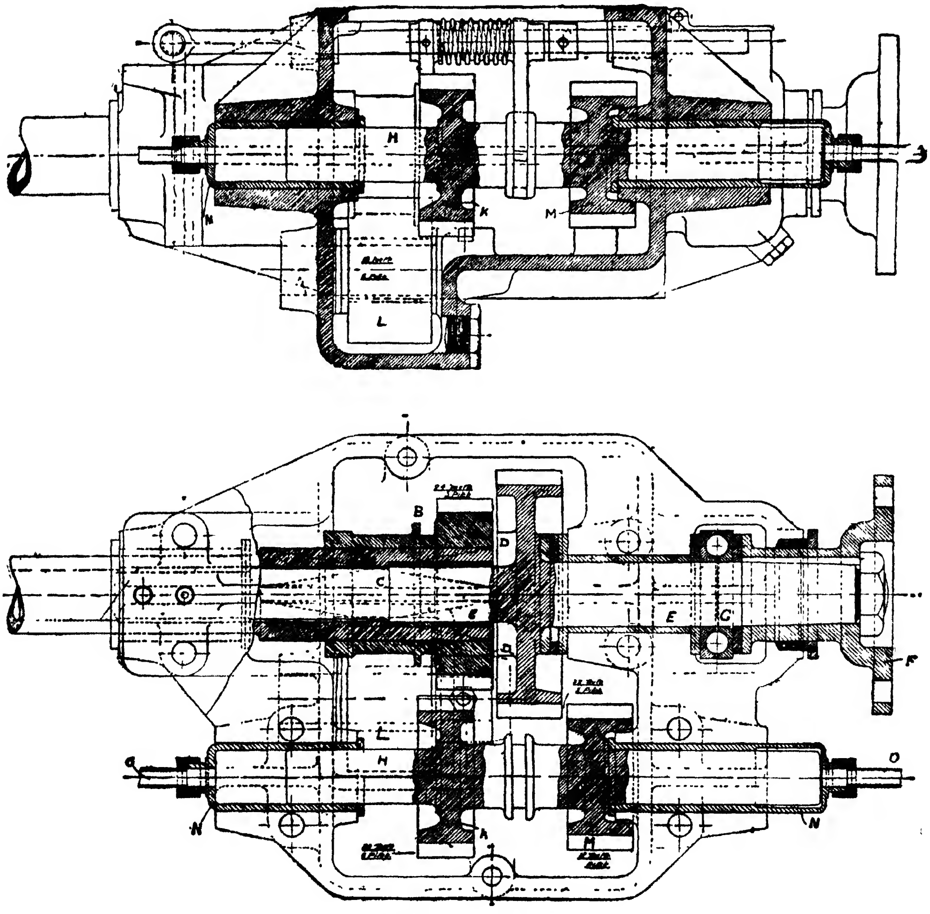


Fig 3.—Napier positive type gear

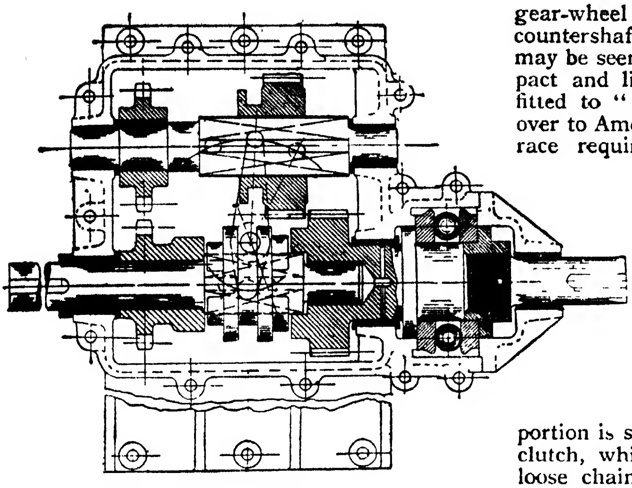


Fig. 4—Section of Parsons gear.

the drawing, till it meshes with L, thus transmitting the drive to the countershaft at the same time that the dog clutch comes out of gear, the same lever that operates B also slides the wheel (M) on its shaft, and moving it also from left to right brings it into mesh with the spur wheel (I), thus giving a reverse drive to the shaft (E).

From a mechanical point of view the gear is an excellent one, and it is, moreover, easily handled : the shafts are short, and so not liable to whip, and they are of an ample diameter. There is the advantage of an absolutely clean ahead drive, when it will be seen no gears are revolving, even idly.

The Napier Gear.

Another gear of the same type, but differently arranged, is the Napier, and which is shown in Fig. 3, in plan and elevation. The action is the same as in the gear just described, but instead of moving the pinion (M) on its shaft, the whole shaft is moved bodily, bringing M into mesh with the spur wheel (D) on the tailshaft, and simultaneously bringing the pinion (K) into mesh with the spur wheel on the layshaft (L). The pinion (B) also has to be brought in mesh with L, and it will thus be seen that three sets of gears have to be meshed to give the reverse. The design from an engineer's point of view is an extremely pretty one, and it works admirably, though a certain amount of skill is necessary in its operation. Of course, it goes without saying with any gear of this type that there must be a separate clutch on the engine shaft, otherwise it would obviously be impossible to get the gears into mesh.

An Example of Chain-driven Reverse.

We now come to the Parsons reverse gear, in which, as already explained, the layshaft is done away with by the substitution of a chain for a gear-wheel drive from the engine shaft to the countershaft. The gear is extremely simple, as may be seen from the drawing, and is very compact and light, and, it should be noted, was fitted to " Wolseley-Siddeley " when she went over to America to comply with the B.I. Trophy race requirements. In the section drawing (Fig. 4) the arrangement can easily be seen; the engine shaft is to the left and tailshaft to the right. There is a loose chain wheel on the engine shaft formed in one with a jaw clutch; a gear wheel is keyed to the tailshaft, and this also is formed with a jaw clutch. The engine shaft is spigoted to the tailshaft, and its centre portion is squared and carries a double-face jaw clutch, which can be engaged either with the loose chain wheel or with the tailshaft. The arrangement of the control lever is indicated in the drawing, and, obviously, if the movable dog clutch is shifted over to the right, it will give a direct ahead drive and the chain wheel on the engine shaft will be quite free. The counter shaft, of course, carries a corresponding chain wheel and also a spur wheel on the squared portion of the shaft. This latter is operated by the small lever that actuates the double jaw clutch, but so arranged that it moves in the opposite direction to the latter; thus, when the jaw clutch is in the ahead position, the spur wheel is over to the left and out of mesh. If, however, the jaw clutch be moved over from right to left, thus engaging with the chain wheel and transmitting the drive to the countershaft, the spur wheel on the countershaft goes into mesh with the tailshaft pinion and gives a reverse drive. In all three of these gears, it will be noted, a substantial thrust bearing to take the thrust propeller is fitted on the after end of the gearbox.

There are, of course, other excellent examples of positive type reverse gears on the market, but the examples given will serve to explain the principle sufficiently clearly.

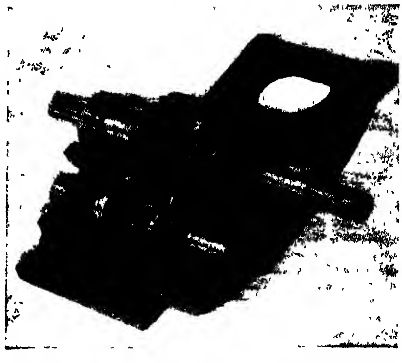


Fig. 5.—Parsons gear with cover removed.

Differential and Epicyclic Gearing.

We now come to the non-positive varieties of gear which require no separate clutch and are operated entirely by a single lever, also as there are no sliding gears to take in and out of mesh, reverse gears of this type may be considered almost fool-proof and, therefore, very suitable for all-round work. Before proceeding to describe actual types of gear, it will help to make the various systems clear if we describe briefly the principle of the differential and epicyclic gears. Differential gears may be sub-divided into two types—the bevel pinion and the parallel pinion varieties: a diagram of the bevel pinion appears in Fig. 6; the engine shafts and tail-shafts are placed as shown, and carry respectively the bevel spur wheels (A and B). These wheels each mesh with the star pinions (S) which are carried in an outer case (T). Now, if this outer case be held rigidly, it is easy to see that if the spur wheel (A) be driven in one direction, it will drive the tailshaft (B) the opposite way through the star pinions (S) so that a reverse is obtained. For going ahead, the case (T) is released, so as to be free to revolve, and A and B are clutched together, thus giving an ahead drive and turning the whole of the gearcase bodily.

The principle of the parallel pinion type of differential is precisely the same, though it is slightly differently arranged. Again, we have spur wheels (A and B) respectively on the engine and tailshafts, wide pinions (M) mesh with the wheel (A) and other wide pinions (N) mesh with B and also with M, as shown in the diagram, all the pinions (M and N) being mounted in a case as before. Here, again, if the case be held rigidly, A will drive the pinions (M), which in turn will drive N, and N will drive B in the opposite direction to that in which A revolves.

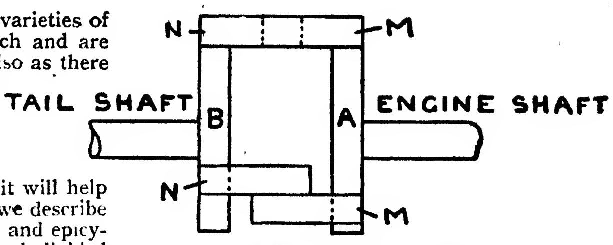


Fig. 7.—Parallel pinion gear.

For driving ahead, the outer case is released and A and B clutch together, so that, as before, the whole case revolves, but without the gear wheels revolving on each other.

We will now consider some examples of the bevel pinion type:—

The Hesse and Savory Gear.

In this gear, which is shown in section in Fig. 8, and which is also illustrated in Fig. 9, the arrangement is quite clear. The bevel gears on the differential can be clearly seen; on the left is the thrust block carried on the engine shaft, and on the right is the tailshaft, spigoted into the engine shaft. Between the differential gear and thrust block is a double cone clutch; the inner and externally-faced member of this clutch is keyed to the tailshaft. Then comes a double-faced member keyed to the engine shaft, while the outer member of all is bolted to one of the differential spur wheels, and is also held rigidly in the case. When driving ahead, the tailshaft carrying the inner member of the clutch is moved bodily forward, thus engaging with the internal face of the double-faced member and giving a direct drive ahead, the propeller thrust serving to keep the clutch in engagement without the use of any springs. For going astern, the tailshaft is pulled bodily aft, bringing this clutch out of engagement and carrying with it the outside clutch which engages with the outer face of the double-faced member. A drive is thus transmitted to the left-hand spur wheel of the differential gear, the right-hand spur wheel of the differential is free on the tailshaft when the gear is driving ahead, but the action of pulling the shaft astern engages it with the dog clutch on the tailshaft, and so a reverse drive is transmitted. This gear affords a slight variation of the principle set out above by reason of the use of the dog clutch, which makes it possible for the ahead drive to take place without the whole of the gearcase revolving. When going astern, as when driving ahead, the thrust of the propeller keeps the clutch in engagement.

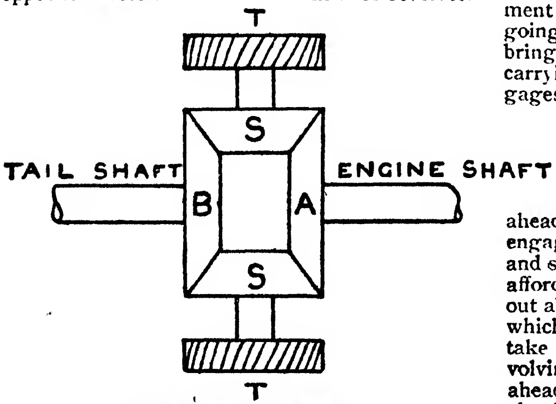


Fig. 6.—Bevel pinion gear.

It might be thought that, in the case of a powerful engine, where the thrust may easily amount to 400lb. or more, it would be impossible to get the clutches in and out of gear, but, as a matter of fact, this is not the case. The actual thrust being known, it is possible to so proportion the size and taper of the clutch faces that there is only a small margin of pressure over that at which the clutches would slip; thus, a comparatively slight pull on the reversing lever suffices to cause a certain amount of slip, there is at once a reduction in the thrust of the propeller, and so the gear can be taken out quite easily. This gear is perhaps as widely used as any at present on the market. In its original form it was rather heavy, and, in our opinion, took up more room than it should have done, but the new pattern which is now on the market represents a very great improvement on the old, being compact and reasonably light.

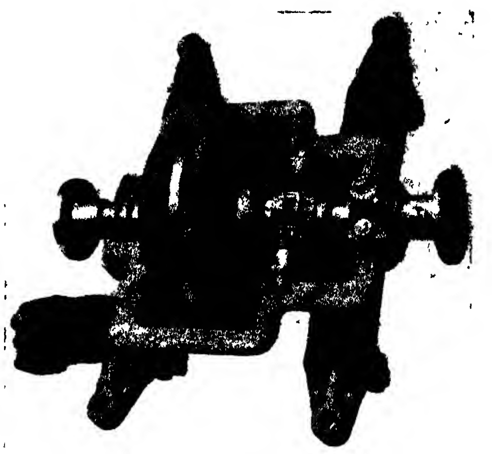


Fig. 9.—The gear with cover removed.

Friction Gear.

We now come to a variation of the bevel differential type, in which the gear wheels are replaced by cones with grooves cut in their faces, as shown in the illustration (Fig. 10) and section drawing (Fig. 11). This gear is manufactured by Messrs. Simpson, Strickland and Co. under the name of "Inder," and the chief point aimed at in its design was to produce a simple and certain method of control that could be instantly brought into operation, which aim has, we think, been fully attained. Keyed to the engine shaft (A) is an internal cone clutch (B), which is bolted to the left-hand bevel spur wheel, the grooves on which are clearly shown and of which the number will vary according to the power to be transmitted. The propeller and shaft on the right carry an externally-faced clutch member (C), this being mounted on a squared portion of the shaft, and at the same time bolted to the right-hand bevel spur wheel (E); the spring (D), which is fitted with ball thrust collars at each end, ordinarily keeps the cone clutch (B, C) in engagement, and so gives an ahead drive.

We will now consider the method of obtaining a reverse: on the after end of the casting (C) is a loose collar (F) carried on two sliding rods (G), which engage at their after end with the reversing lever. When these rods are pushed inwards against the clutch spring, the two cones are disengaged and the propeller shaft is thus free. A further motion of the reversing lever carries the inner member of this clutch and the spur wheel (E) still further towards the left and engages the star pinions (H) of the differential, thus giving a reverse drive. These star pinions are mounted on pins (J), which are carried in blocks (K), leaving them freedom for small lateral movement. Thus, for the reverse drive the differential gear is, so to speak, squeezed together. A comparatively small amount of pressure is sufficient to give the necessary grip for the reverse, and directly this is released the pinions disengage and the gear returns to the neutral position, a further movement of the lever bringing the cone clutch again into operation for the ahead drive.

We now pass to the parallel pinion type of gear, the general principles of which, as already explained, are exactly the same as in the types just considered, though, naturally, there are for the ahead drive.

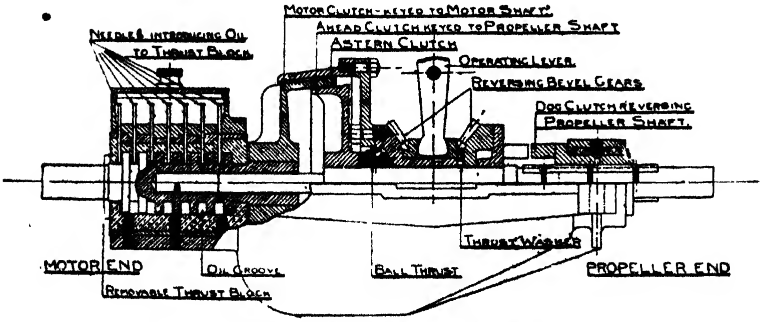


Fig. 8—Section of H. and S. gear.

A Self-locking Gear.

Among the best examples of the parallel pinion type is the "Ideal" gear, manufactured by Messrs. Dickinson and Burne (see Fig. 12). Like the last-described gear, it does not depend in any way upon the propeller thrust for keeping in engagement, and, therefore, the thrust block is aft instead of forward of

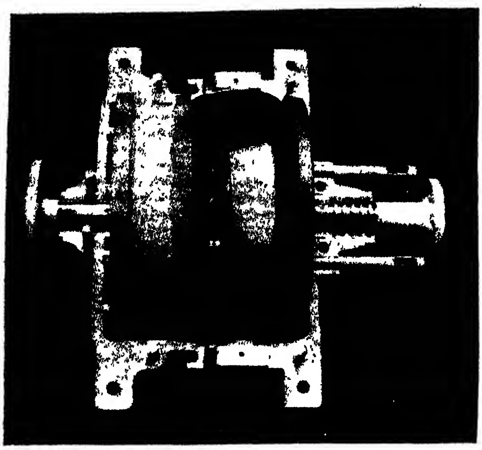


Fig. 10.—A bevel pinion friction gear.

the gearcase. Like the Hesse and Savory gear, there is a double cone clutch, the double-faced member (A) of which forms part of the gearcase (B), being bolted to it by spindles (C); the engine shaft (D) carries the driving pinion (E), which is connected to the pinion (F) through a train of parallel pinion gears, as already explained. These pinions are not shown in the illustration; F is keyed to the tailshaft (G), which also carries an externally-faced member (H), engaging with the double-faced member of the clutch (A). For going ahead A is pulled forward by the reversing lever, and engages with H; the differential gear is thus locked and revolves solid with the shafts going ahead. For going astern A is engaged with the outer clutch member (K), which is rigidly attached to the frame; the gearcase is thus held and a reverse drive is obtained. The arrangement of the reversing lever is rather interesting and provides a system for automatically locking the gear in whatever position it is put. The lever works in a recessed collar (L) and gives fore-and-aft movement to the rollers (M), which are forced apart by springs shown on the right of the illustration (Fig. 12); the rollers engage with toggles or bell-cranks (N), which are pivoted at O, and whose outer arms (P) engage with the spindles of the clutch member (A) giving it the fore-and-aft motion already referred to. From the shape of the inner arms of the toggles it is evident that a fore-and-aft motion of the rollers will gradually force the clutch either ahead or astern into engagement, and, further, that, either in the neutral position, full ahead or full astern, there is no inclination to throw in any particular direction.

A Coil Clutch Gear.

Another example of the parallel pinion type may now be considered. It is manufactured by the Coil Clutch Company, and, as the name implies, is remarkable chiefly for the system of coil clutches employed in place of the more common cone type. Referring to Fig. 13, A is the engine shaft and B the tailshaft, and, with a substantial thrust bearing (D), the pinions (E and E^1) are keyed respectively to A and B, and it may here be noted that A is spigoted into B with a ball bearing between the two; parallel pinions (G and G^1) complete the differential gear in the ordinary way; that is to say, A drives G, G drives G^1, G^1 drives E^1, G and G^1 are carried in a case (F), which also forms a brake drum. At the forward end of the case another brake drum (K) is mounted on the engine shaft, and round it is a coil spring (L), the left-hand end of which is anchored to the case (K), the loose end to the right is just above the taper pin (O), and for an ahead drive this pin is forced by the reversing lever acting on the sliding collar (N) hard against this loose end, contact being preserved by means of the tongue (M); the coil thus tightens up on the drum (K), and the whole of the gear being locked, an ahead drive is obtained; J, it may be mentioned, is merely an outer case intended to protect the coil clutch just referred to. For going astern, there is another coil clutch (H) operated by an arrangement of levers, shown dotted. One end of the coil (H) is anchored to the frame at the point (I), and the other end being tightened up outside of F, holds the case rigidly, and a reverse drive is obtained through the differential gear.

Epicyclic Gears.

We will now pass on to the epicyclic type of gear, the principle of which is show diagrammatically in Fig. 14. The pinion (A) may be considered as keyed to the engine shaft, meshing with it, and carried on a frame are star pinions (C), which also mesh with the internally-toothed wheel (B) keyed to the engine shaft. If the frame carrying C be held rigidly and A revolved, it will be found that B will be driven in the opposite direction, giving a reverse motion

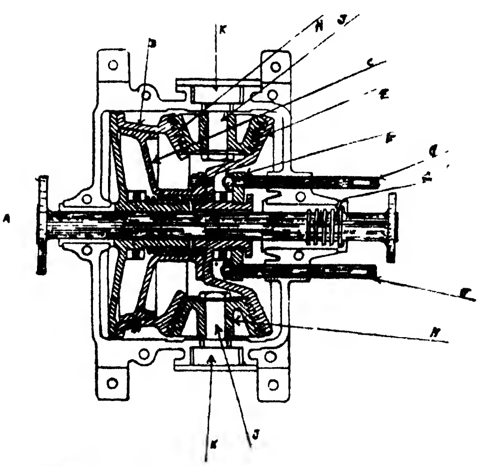


Fig. 11.—Section of "Inder" reverse gear.

for going ahead; the whole gear would be locked in the manner explained for differential gears and would revolve solidly with the shaft.

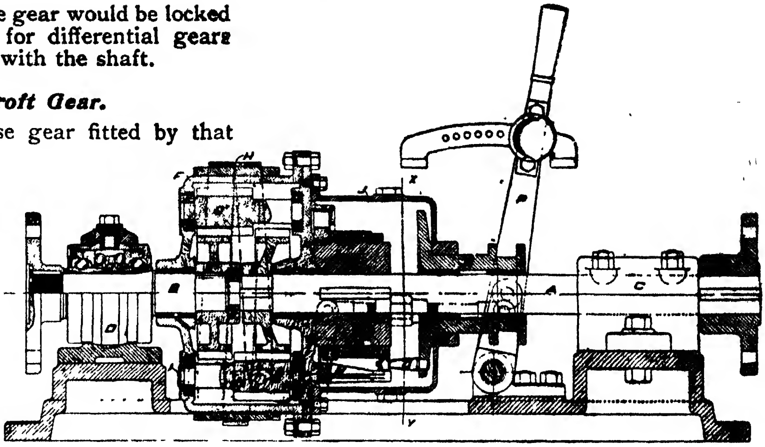


Fig. 13.—A gear with coil clutches.

The Thornycroft Gear.

The Thornycroft reverse gear fitted by that firm to nearly all their boats affords an excellent example of the epicyclic type, and, as will be seen from the sectional drawing, Fig. 15, its mechanism is extremely simple. The gear belongs to the variety in which the thrust of the propeller is utilised to hold the clutches in engagement, and so the thrust bearing is forward of the gear. There is the usual double-cone clutch arrangement, the double-faced member being keyed to the tailshaft and carrying also the star pinions of the epicyclic gear; the inner externally-faced member of the clutch is keyed to the engine shaft, and the outside of all forms part of the engine casing and is always held rigidly for an ahead drive, the double-faced clutch member is moved forward, and engages with the inner member carried by the engine shaft and also forming the internally-toothed wheel of the epicyclic train; the gear is thus locked and gives a solid drive through the train of gears, the thrust of the propeller holding the clutch in engagement. For going astern the double-faced clutch member is pulled aft, carrying with it the star pinions of the epicyclic train, but these pinions being very wide, of course remain in mesh. Continuing the astern motion, the outer face of the clutch engages with the inner face of the external member, forming, as already explained, part of the rigid case. The frame carrying the pinions of the gear is, therefore, held and a reverse drive is obtained. An excellent point that will be noticed about this gear is the extremely short distance between the shaft centres and the great length of the spigot. In place of the usual direct-operating lever, a screw gear is employed, so that very great power can be obtained, and it is possible to so shape the clutches that there can be no possibility of slip, it being possible to take the clutch out against the full thrust of the propeller. It should, perhaps, be explained that in this gear the propeller shaft itself does not move fore and aft, the movable part of the gear being on a sliding key.

The Hele-Shaw Gear.

Lastly, we come to another epicyclic gear. This is an arrangement of multiple disc clutches in place of the cone type.

The gear consists of an engine clutch, a reversing clutch, and an epicyclic gear. The clutches are of the multiple disc type, with annular V grooves in the discs, as will be seen in the sectional illustration (Fig. 16). These discs

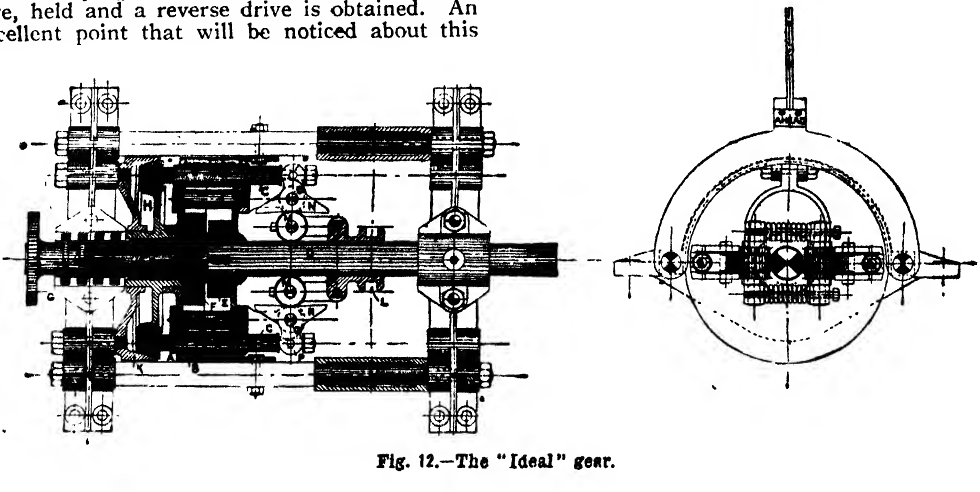


Fig. 12.—The "Ideal" gear.

are alternately keyed to the outer casing of the clutch and to a boss on the shaft to be driven.

They are kept forced into engagement by means of powerful springs, and, when the clutch lever is withdrawn, thus relieving the master springs (as they may be called), the several plates are separated from one another by small clip springs attached to each, in which position the two sets of plates or discs are free to revolve independently.

The whole clutch case is charged with oil, and there is a considerable amount of slip between the plates when first the clutch is let in, thus making it very sweet, so sweet, indeed, that it is almost impossible to say exactly when the full drive is taken up.

Referring to the illustration, the engine clutch (EC) is used simply to connect the engine shaft with an intermediate shaft carrying a pinion (EG). The outer member of the reversing clutch (RC), carrying one set of plates, is keyed to the tailshaft, and the inner boss, carrying the other set of plates, is keyed to the intermediate shaft. To go ahead, therefore, it is only necessary to put the clutch (RC) into engagement and let in the engine clutch, when a solid drive ahead will be obtained. The pinion (EG) meshing with the planetary pinions (P) of the epicyclic gear carries round the outer casing (BD), since the internally-toothed drum (IG) of the gear is bolted to the case of the clutch (RC) and must revolve with it. To go astern, the reversing lever is pulled aft, thereby first disengaging the clutch (RC) and giving a neutral position; a further movement applies a band brake to the gearcase (BD), which is thus held fast. The intermediate shaft driven by the engine through the clutch (EC) then rotates the planet wheels on their own axes, and these drive the member (IG) in the opposite direction. This, it will be remembered, is bolted to the outer case of the clutch (RC), which is keyed to the tailshaft, and, therefore, gives an astern drive. This gear runs as smoothly as any on the market, and its only weakness lies in the fact that when going astern the two sets of discs of the clutch (RC) are revolving in opposite directions. This sets up a good deal of friction, but it is not, perhaps, of very much consequence, as the reverse has only to be used for short periods at a time. In the original gear this slip was going on all the time the boat was running ahead, and the clutch used to get fearfully hot, and in more than one case seized up altogether. But now that this trouble has been eliminated, it must certainly be classed among the best gears yet devised.

A Belt Reverse.

This brief review of reversing gears may now be brought to a close with the consideration of a type that we personally consider equal to any on the market, though it has been comparatively little used, and it is certainly as simple and cheap as any that could be devised, and at the same time quite up to the comparatively small amount of work that a reverse gear is called upon to perform; we refer to the endless belt reverse, the principle of which is illustrated herewith, Fig. 17. In the right-hand portion of the figure A and B are pulleys mounted respectively on the engine and tailshafts, and in practice there would be a clutch between them. Overhead are jockey pulleys (C) arranged as shown. Starting from A, a belt runs over one pulley (C), down the other side of it, round B and up the other side over the other jockey pulley, thence down again and underneath A. If this arrangement of the belt be followed out, it will be found that a reverse drive is obtained between A and B. For driving ahead, the clutch between A and B is, of course, engaged, and the jockey pulleys are allowed to drop, thus leaving the belt quite slack. To put in the reverse, the clutch is, of course, taken out and the jockey pulleys merely raised to tighten the belt. For simplicity, lightness and

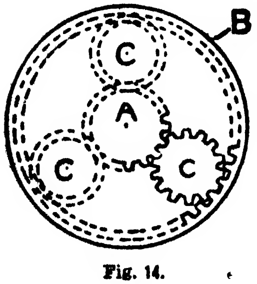


Fig. 14.

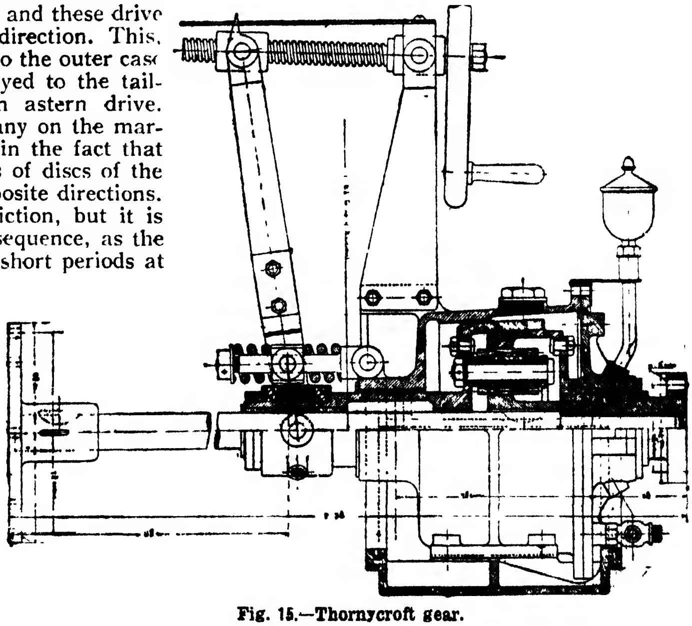


Fig. 15.—Thornycroft gear.

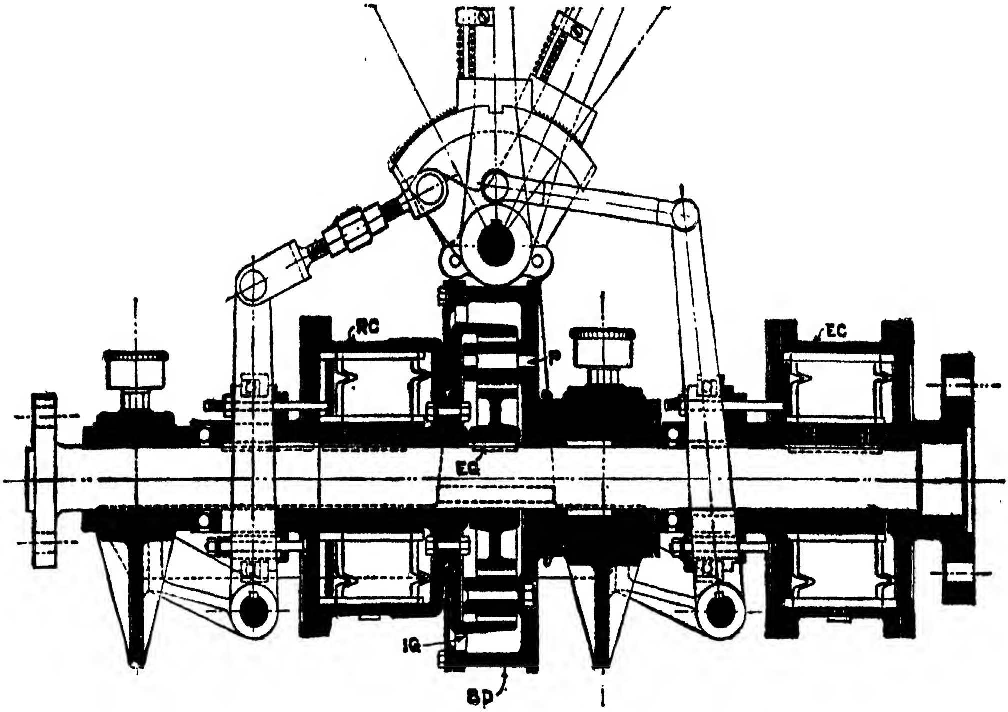


Fig. 16.—Hele-Shaw grooved plate-clutch reversing gear.

cheapness such a reverse is hard to beat, and it is a surprise to us that it is so little used; it is made use of by the Bergius Engine Co., and we have also come across it in one or two of the old Mercédès racing boats, and also last year in "Defender" and elsewhere.

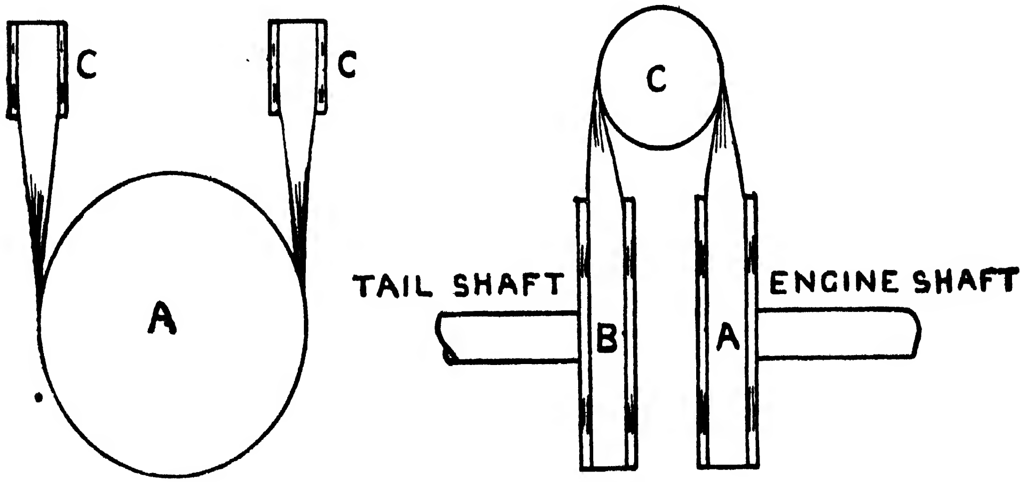


Fig. 17.—Diagram of belt reverse.

Reversing Propellers.

The third method of reversing the boat consists of altering the pitch of the propeller, or, in other words, in converting a right-handed propeller into a left-handed one, or vice versâ, and all reversing propellers, as they are called, are modified arrangements for producing this desired effect. Of patterns of reversible propellers there are an almost unlimited number, but the principle of nearly all is the same. The propeller shaft carrying the boss is hollow, and passing down it is a rod that rotates with it, but is capable of movement in a fore-and-aft direction, the end of this rod being attached to the mechanism that shifts the blades. Alternatively, the shaft may be solid with a sleeve over it. The mechanism varies, of course, in every design, in some cases consisting of toothed gears, in others of slotted-discs, with which pins on the roots of the blades register. The great object to aim for in any design is to obtain a sufficiently strong root to the blade. Most of them seem strong and rigid when new, but unless the design be a very good one age produces a great deal of shake, and the efficiency of the propeller is much impaired. Broadly speaking, deep roots with wide collars set in large bosses will naturally give the best propeller from a mechanical point of view, but, on the other hand, a large boss does not make for efficiency, and every design must, therefore, be a compromise to some extent. In the actual reversing mechanism the great points are, of course, to obtain a good mechanical advantage, combined with absence of backlash, while it should be, so far as possible, irreversible.

Probably the first practical motor-propelled vessel in this country, a boat placed on the water by Messrs. Priestman, was equipped with a reversing propeller, and the number of these propellers placed on the market during the last few years is astonishing, as also is the variety in their design and construction. Perhaps the greatest obstacle that designers have had to contend with is the fact that owing to the leading edge of the propeller blade receiving a greater reaction or thrust from the water than the terminal edge, there is always a tendency for the propeller blade to rotate on its axis or increase its pitch. Anyone who has ever had to handle a reversing propeller actuated by a lever will have noticed the tendency there is for the lever to anticipate the operator, and fly full ahead or full astern, whichever way it is being directed.

The effect of this is that the propeller will

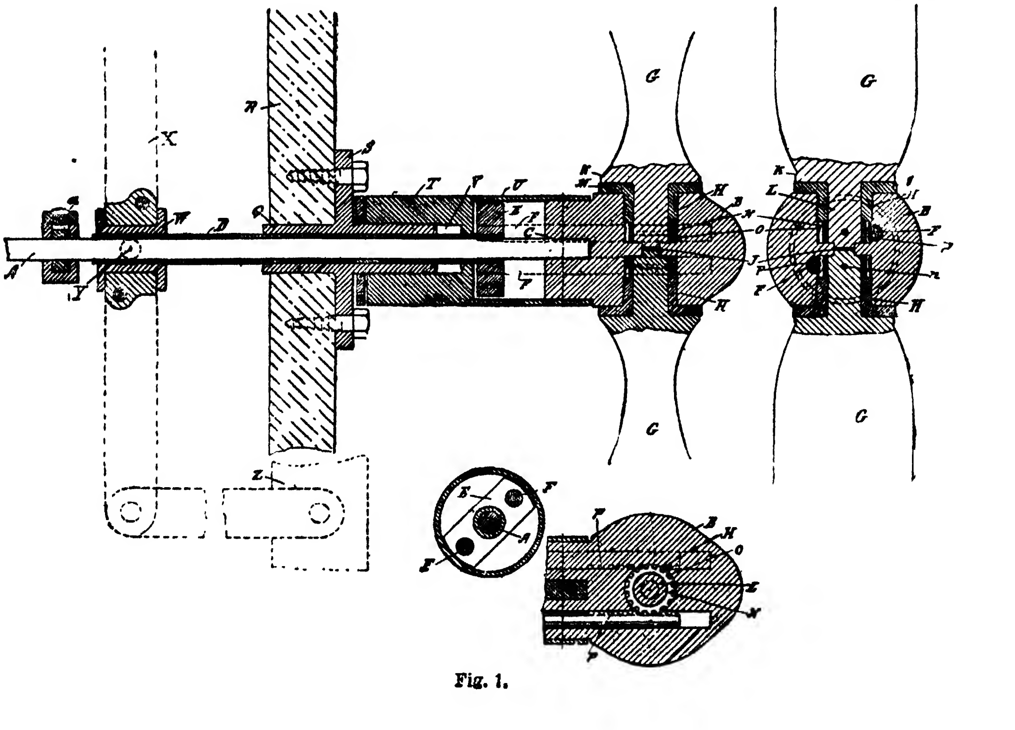


Fig. 1.

take advantage of all back-lash, so that it is practically impossible for the propeller to be set at its neutral position.

This tendency can be to a certain extent obviated by curving the surface of the blade, so that the pressure is approximately equal on both terminal and leading edge, but this unfortunately aggravates the fault in the astern position.

There are other sources of weakness which will be explained as we describe some of the types.

An Early Form.

It will be observed (Fig. 1) that this propeller has two blades, whose axes coincide, and whose shanks are fitted with pinions, which pinions mesh with two racks that are actuated in a fore and aft direction by means of a sleeve sliding on the propeller shaft.

(A) is the propeller shaft that is keyed to the engine, and which terminates, in the case of a right-handed engine, in a left-handed thread (C), by which means it is secured to the propeller boss (B). Enveloping the shaft (A) is a sleeve or tube (D), secured to and actuated by a collar (W), which engages in a lever (X) and trunnion (Y), which sleeve is secured by means of a right-handed thread to a plate (E). This plate carries the two circular racks (F), and holes are provided in the boss (B) to lead these racks so that they mesh with the pinions, which are formed on the blade shanks.

The engine rotates the shaft (A), which rotates the boss (B), which in turn, through the rack fork (FE), rotates the sleeve (D), and it will be noticed that both D and A are carried in the stern bearing (Q).

It should be quite clear that the action of moving the sleeve, and, therefore, the rack fork fore and aft, will have the effect of rotating the blades (G) in the same *virtual* direction, but, of course, the movements are opposed in relation to each other. The blades are secured in the boss by means of a split screw collar (M), which, bearing on the outer edge of the pinion, prevents the blades from being forced outwards. It will be noticed that this formation provides a substantial shoulder bearing and shank bearing, and that a small spigot (J) further helps to support the blade.

A very excellent feature in connection with this gear consists of the sleeve (TU), which is screwed on to the stern bearing (Q), and forms a stuffing box (V), while the projection (U), enveloping as it does the propeller boss itself, albeit it is a slack fit, takes up any undue strain that may be imparted to the propeller, and as it is stationary, to a certain extent prevents the collection of weeds.

The stop (a) which prevents the sleeve being thrust further than is desired, is made necessary by the fore-mentioned tendency that these propellers possess to set themselves as far ahead as possible. In this case, the sleeve travels up until it is arrested by the stop (a), which relieves the bearing (W) and lever (X) of all further strain.

A great disadvantage of the reversing propeller is that, owing to the fact that the direction of rotation cannot be reversed, it is somewhat difficult to remove weeds which may have accumulated, and therefore a reversing propeller is not at all desirable in weedy waters.

Fig. 2.

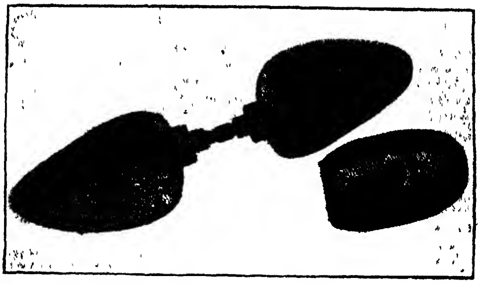


Fig. 3.

As an example of the field there is for ingenuity in connection with reversing propellers, we illustrate (Figs. 2 and 3) a propeller which consists of two blades screwed into a split boss by means of a coarse pitch thread, and distanced by means of a rod screwed right and left hand, and provided in the middle with a rack, this rod being placed co-axially with and screwing into the two blades. This spindle is operated by a rod terminating in a rack passing through a hollow shaft, and any movement of this rod will rotate the spindle and move the two blades in a centrifugal or centripetal manner, and, by means of the coarse threads on their shanks, will cause them to rotate.

It will be fairly obvious, owing to the very great strains that will be encountered, and the large amount of movement of the blades a very small quantity of back-lash will allow, that this construction might be modified to some extent for prolonged use.

From what has been said it will be seen that reversible propellers are wrong in principle from a mechanical point of view, but that there are certain classes of vessel in which they are preferable to a solid propeller and reversing gear, namely dinghies, where a reversing gear, besides taking up a lot of room, might be out of

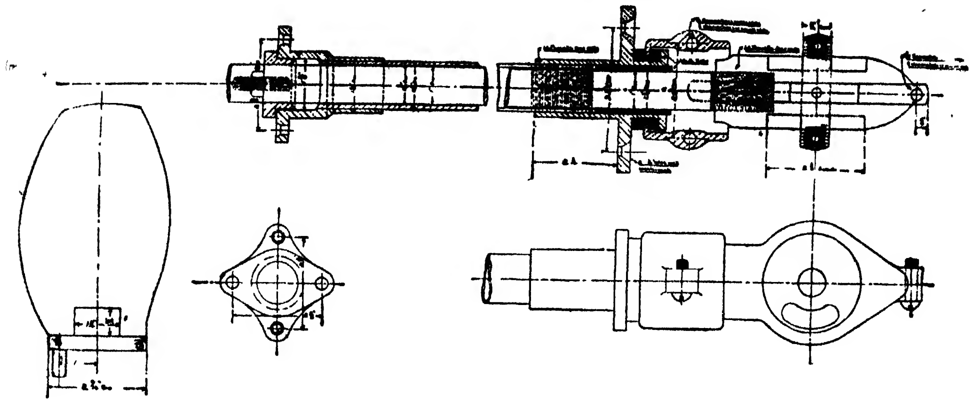


Fig. 4.

all proportion to the rest of the boat so far as expense is concerned, and auxiliary craft which, when under sail, must be able to feather their propellers or a very heavy drag will be set up.

An Open Boss Propeller.

An example of a simple open boss type of reversing propeller is next illustrated (Fig. 4).

The propeller boss has circular recesses cut on either side, into which flanges on the roots of the blades fit; a short spindle with screwed ends passes through the boss and also through the flanges, which are kept in position by nuts done up just tight enough to prevent shake without causing the blades to bind on the boss. There is a pin on the inside of the blade flange, and near the circumference, which engages in a slotted disc inside the boss. This disc is attached to a sliding shaft inside the tail-shaft, the latter being hollow, and, as this inner shaft is moved fore and aft, the slotted disc carries the blades round through a certain angle. The arrangement is very simple, cheap to manufacture, and for the type of boat for which it is intended, perfectly satisfactory. For high powers it is manifestly unsuitable, for wear of the parts would be very rapid under a heavy strain, and the blades would become very unsteady, having only one flange each to support them.

Closed Boss Construction.

Of the closed boss type there are several varieties, though the general principle of a reciprocating motion between shaft and boss is common to practically all, and the two makes most in evidence may now be dealt with.

In the first (Fig. 5) the boss is halved and hollowed out internally. The blades are held in bearings formed in the two halves, and have flanges equal to about a quarter of the blade

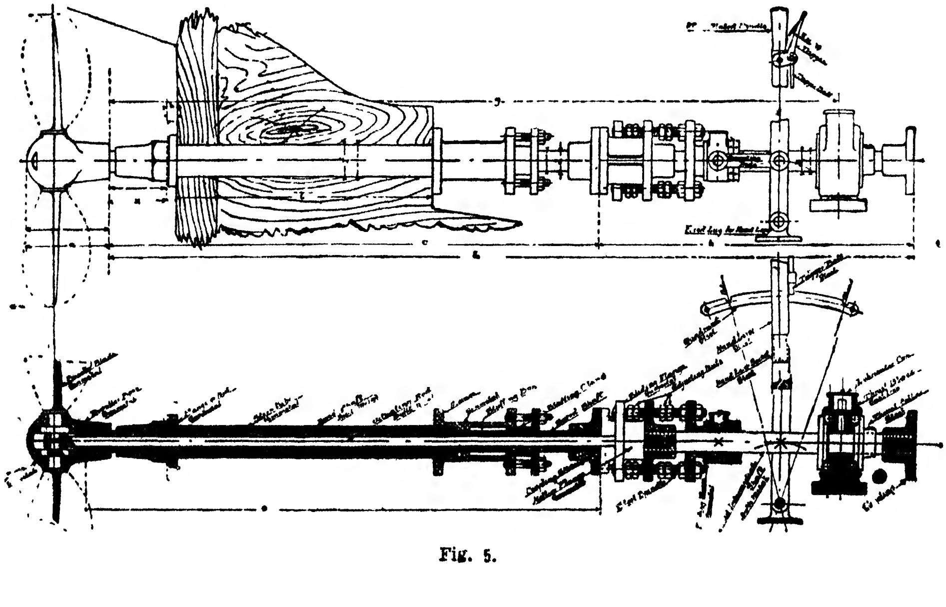


Fig. 5.

length inside the boss. The blades are free to rotate, and between them is fixed a rectangular block carrying pins which fit into slotways cut in the blade flanges. The block can be moved in a fore-and-aft direction by means of a rod passing through the centre of the shaft, which is hollow. A suitable contrivance inside the boat transmits the movement to this rod from the lever, and it will be readily seen that any movement imparted to the block in a longitudinal direction produces a corresponding movement of the blades.

The features of the above design are the simplicity of the boss and rigidity of the reversing mechanism. The blade bearings are flat, and prevent the possibility of the blade cornering. The propeller shaft is not slotted to take the reversing mechanism, but a special hollow casting is used which does not impair the strength of the shaft. Two screwed spindles connect the cross-piece in this casting to the sleeve, which have lock-nuts serving the double purpose of regulating the pitch and transmitting the pressure of the blades from the inner rod to the thrust-block.

Another design is illustrated in Fig. 6, the distinctive feature of which is the long block or prism in the boss. The purpose of this is to give the blades a complete bearing at whatever position the block may be in. It will also be noticed that the blades are dome-shaped at the roots, by which a more lasting bearing is claimed. The reversing mechanism is extremely simple, the shaft being slotted and a sliding sleeve fitted over the slotway controlling the cross-piece. The range of the propeller is limited by stop collars on the shaft, which, as in the case of the other propeller, also serve to take the thrust from the blades.

As far as the moving of the blades is concerned the system is perfection, and there would be no question raised as to the efficiency of the reversing propeller, were it not for the stresses produced by the turning moments of the water pressure on the blades when the motor is driving. The success of the propeller depends entirely upon the correct balancing of the blades, combined, of course, with a suitably constructed inboard gear, so that the water pressure is equal on either side of the blade. Too much area on the leading side causes the blade to jump forward from neutral to ahead or astern, while too much area on the following side of the blade will give it a tendency to go into the neutral. In the latter case also, heating of the reversing gear will ensue, as the pressure will not be thrown on to the thrust-block, but will be taken on the sliding sleeve. This fact seriously handicaps the designer of reversing propellers who aims at maximum efficiency, and it accounts for the "wheels" without any pretence to design that the market was once flooded with. Nevertheless, the reversing propeller has a wide scope of utility. The ability to adjust the pitch renders the reversing propeller more efficient for cases where trials with solid propellers of different pitches are not possible. In large installations the strain when reversing is enormous, and for this reason a clutch must always be fitted, and it is certainly a great advantage even in a boat of small power.

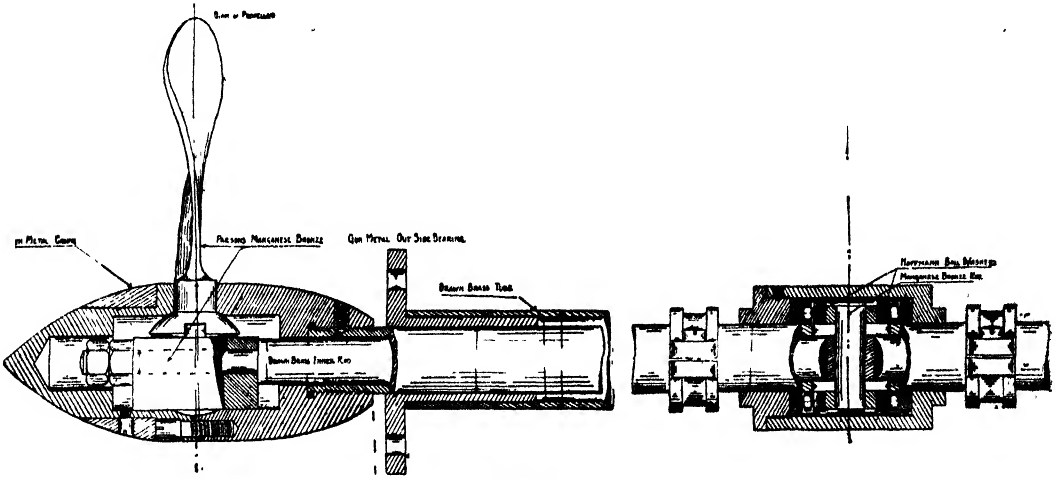


Fig. 6.

Another propeller in which the boss construction is modified is instructive as showing another way of applying the same principle. Each blade (Fig. 7) has the usual double flange at its root to hold it in the boss, and in addition carries a short crank-arm with a stud or crank-pin at its end, so that, by rotating this pin, the blades can be feathered. The feathering is effected as follows: The propeller shaft is hollow, and contains a rod, squared at the end, which can be moved fore and aft by an ordinary control lever. The squared end of this shaft is inside the boss

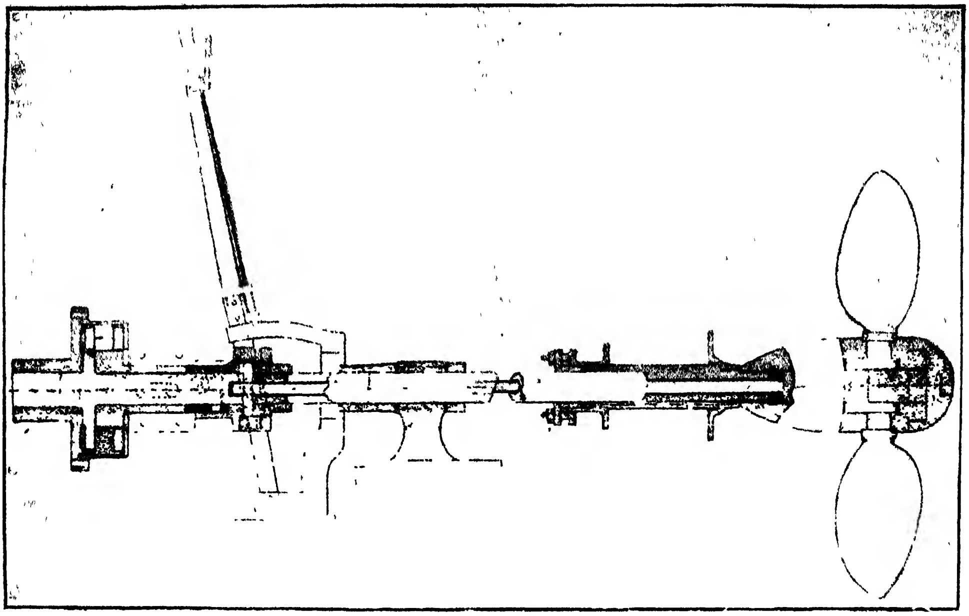


Fig. 7.

of the propeller, and, of course, rotates with it, and has, moreover, diagonal slots running across its opposite faces. The studs on the crank-arms of the propeller blades engage in these slots, and as the shaft is moved fore and aft the blades are worked through an angle sufficient to give a full pitch ahead and astern. The above description is applicable to a two-bladed propeller, but exactly the same principle could be applied to a propeller with three blades, it being only necessary to substitute a triangular for a square-ended movable shaft.

The mechanism is very simple, and practically cannot get out of order, besides which the interior of the boss is made extremely accessible. It is split longitudinally for rather more than half its length, starting from the after-end, and across a diameter which passes through the roots of the blades, so that by removing the loose part of the boss the blades can at once be taken clear away. To secure the two parts of the boss there is a large screw cap on the after end, fitting right over the ends of both portions, while the forward end of the loose section is kept in position by slightly under-cutting the main piece of the boss and fitting the loose piece into it.

Closely allied to the reversible propeller is the variable pitch type, the object of which is to provide a means for adjusting the pitch of a propeller to suit varying requirements. This adjustment, of course, has to be done when the vessel is out of the water and the propeller stationary; it cannot therefore be classed as a reversing propeller—in fact, it is not intended to reverse; but the arrangement is very useful for trying the effects of different pitch. With the addition of interchangeable blades of different areas, its scope for testing purposes may be considerably increased (Fig. 8).

The shank of the propeller blade carries a crank-pin, which engages in a fork, which fork can be moved fore and aft by rotating a specially formed nut arrangement in the end of the propeller box. This same principle, however, is in

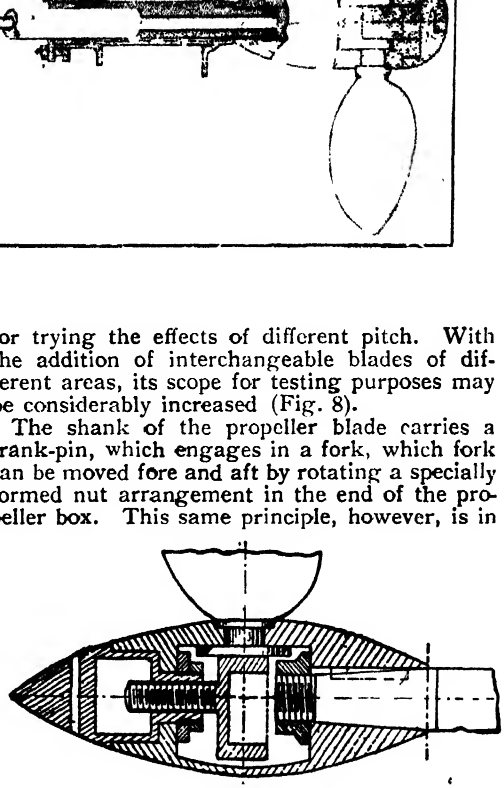


Fig. 8.

many instances made use of for reversing propellers by using instead of the aforesaid nut a rod or sleeve actuated from inside the boat to operate the shaft.

Yet another distinct method of reversing a propeller consists in arranging the actuating rod in the hollow centre of the propeller bracket, this rod being worked from the engine room through a series of other rods and bevel wheels. This system obviates the necessity for a double propeller shaft, but the introduction of bevel wheels increases the back-lash, and it is slow in operation.

NOTES ON MACHINERY INSTALLATION.

Points to Remember.

The motor should be of first-class design, workmanship, and material throughout, and this can only be guaranteed when it is obtained from a maker of experience and high standing, who has a reputation to lose in the event of failure.

The principal points to be desired in a marine motor are reliability and steady running, moderate revolutions, ample width of arms on crank-case to be bolted to the bearers, lowness of weights, compactness of design, absence of all unnecessary springs and tricky fittings likely to rust up or go wrong when exposed to the weather, ease of access to all parts for inspection and repair, and, above all, an efficient reversing gear and clutch, or a reversible bladed propeller, with efficient lever or screw mechanism, which will not fly from full ahead to full astern whenever the lever is moved.

The question of installation is greatly dependent on the purpose for which the boat is to be used, but we may take it as an essential in all cases that the installation should be carried out by someone who is thoroughly conversant both with marine work and with the particular motor in question. Special attention should be paid to lining up the shaft and to the bending and lead of all piping and connections. None but proper screwed cone-faced unions should be used, and the tanks should be of copper, brass, or galvanised steel with well-made joints, all holes for filling plug and fittings being properly re-inforced. If the tank is of large size and for sea work, strong baffle plates should be fitted, to prevent the fuel washing about in the tank in a sea.

All piping, batteries, and wires should be well protected, both against weather and against chance blows, and the motor itself should be properly cased in, except in the smallest dinghies. Drip trays should be fitted under the motor and carburetter to catch any oil or fuel leakages, and efficient circulating pumps with properly arranged suction inlets are a necessity.

How to Avoid Sources of Trouble.

Always carry an ample supply of tools.

Don't use rubber jointing in any form.

Sooty valves indicate too rich a mixture.

Always carry a fire extinguisher of some kind.

Water-cooled or funnel exhaust is the best to adopt.

Use soap to stop a petrol leak; it is far better than red lead.

Always insist on having a tail-shaft with in-board stuffing box.

Don't use a plain eccentric pump for the water circulation on fast-running engines.

Firing back into the induction pipe is caused by weak inlet valve springs.

Loss of compression is often due to the exhaust valve stem seizing in its guide.

In the low-tension make-and-break system the break should not exceed ⅛in.

Uneven running in a two-stroke engine usually denotes an insufficient supply of fuel.

A weak battery or cool combustion chamber will produce practically the same effect.

It is not good practice to pump greasy bilge water through the cylinder jacket.

Do not give a reversible propeller its full pitch if doing so causes the engine to labour.

Don't put more oil in the crank case than is sufficient to just touch the big end of the connecting rod.

A bad joint at the cylinder head may sometimes be cured by the use of sheet lead packing.

Trouble with an Eisemann magneto is usually due to the make-and-break adjusting screws.

Some plugs spark properly outside the cylinder, but may yet prove defective when under compression.

Do not choose an engine with a long stroke unless it runs at slow speed, as the vibration is excessive.

In stopping a petrol motor, use the switch. In stopping a paraffin motor shut off paraffin at the main cock.

Do not let any of the ignition apparatus get damp, and do not use a higher voltage battery than the coil is designed for.

A petrol gauge is sometimes a cause of trouble through leakage, but when well fitted will generally be found very handy.

Nearly all motor troubles arise from the most simple causes, 80 per cent. of faults being with ignition and fuel supply.

Do not use a silencer which has small holes in it, unless it is easily accessible; they are sure to require an occasional clean out.

Broken valve heads should not be able to reach the piston; the valve pockets should be so designed as to make this impossible.

Don't use a plug or stop-cock for petrol; use a screw-down needle-valve, and have a vent-cock fitted to the petrol tank if gravity feed is employed.

Use a copper petrol tank in preference to one of galvanised iron, as the zinc is liable to scale off the latter and choke the spraying jet of the carburetter.

All fuel pipes should be of best solid-drawn copper tube. Put an efficient strainer in the fuel supply pipe; it will save much inconvenience and delay from stoppage.

Use strongly made unions ground to an accurate fit; if washers are required, leather should be avoided; vulcanised fibre, or, failing this, sheet lead, is more suitable.

A useful fitting is an electric lamp of low voltage type. It is very economical in current consumption, and two 4-volt cells will light a lamp of 7c.p.; the light is white and penetrating; 4-volt lamps of 3c.p. can also be obtained.

In Commission.

Always carry spare plugs and other parts likely to require replacing in a hurry, also a good kit of simple tools.

See that your boat has efficient circulating pumps, and that the sea-cock or inlet is easily accessible for the removal of weeds, etc.

A metal tray should be placed under all marine motors to prevent the waste lubricating oil and leakage from the carburetter getting into the bilge water; this is especially necessary in the case of petrol motors fitted with carburetters which are liable to overflow at times.

See that there is plenty of fuel in the tank before starting on a run, and that the fuel cock is open before trying to start the motor. These are such simple matters that they escape the notice of many people more frequently than would be supposed. A float gauge in the tank is very useful.

All but the smallest motors should be fitted with a thoroughly efficient clutch if the boat is intended for use on a river where there is much traffic and locks are crowded. Indeed, a clutch is very useful even on boats for sea work, although in many cases they are not so fitted, unless of high power.

If you have no strainer fixed in the filling hole of the fuel tank, fix a piece of fine copper gauze in the funnel through which the petrol or paraffin is poured into the tank, also arrange some form of water trap to prevent any water which may have got into the tank being drawn off with the fuel into the carburetter.

It should be remembered that a marine motor is nearly always running on its full load, consequently the strains and wear and tear are similar to those which would be experienced in a car if it were to be run uphill all day. For this reason, all parts of a marine motor require to be stronger in proportion to the power than the usual car practice.

Avoid very light fast-running motors for cruising and general purposes, as these engines, while possibly very suitable for racing boats, are quite unfit for ordinary marine work, both on account of their liability to get out of order when subjected to heavy strains and rough work on a boat, and also because high engine speeds are not conducive to the greatest propeller efficiency unless combined with a corresponding speed through the water on the part of the boat.

Aluminium soon corrodes in sea air, perhaps even more rapidly when exposed to the air and spray than when it is actually submerged in salt water. Copper, in conjunction with aluminium, increases the corrosive action of the salt air and water. In view of this quality in the metal, it should be avoided as much as possible in all motors intended for sea work, but where it has to be used, as in the case of racing boats, it should then be well coated with some paint or enamel, which is practically impervious to air and water.

Test your accumulators frequently, and be sure that they are sufficiently charged, or in the case of magneto ignition, see that the magneto is running properly, and is not over-lubricated. In either system, overhaul the wiring and plugs to see that a good spark is being produced. Do not forget that in motor boats used on the sea, great trouble frequently occurs through rust and corrosion of various parts of the firing system owing to the damp salt air; also short-circuiting is more common from spray, etc., than in the case of river boats.

A good marine motor for ordinary purposes should have ample width across the bearer arms to clear the flywheel, and thus enable the engine bearers in the boat to be carried right fore and aft. The want of this is a very serious fault in many of the American two-stroke motors which have flywheels projecting beyond the inside width of the bearers, consequently, the latter have to be nearly cut asunder to obtain sufficient clearance. A wide base is also desirable on account of its extra stability, and the decreased vibration resulting therefrom.

ELECTRIC IGNITION.

In the engine section of this manual, the necessity for providing some means of igniting the explosive mixture in the cylinder was explained, and it will be remembered the four-stroke engine required some appliance to operate every other revolution, while two-stroke motors must have their charge ignited every revolution. In consequence of this, different timing arrangements have to be made for the two classes of engine, but as the four-stroke motor presents far the greater number of difficulties, all ensuing diagrams, etc., are for this type, and once the principles of ignition applied to these engines are thoroughly mastered, there will be no difficulty, with the help of some short notes at the end of this section of the Manual, in dealing with two-stroke motors. There is one other point that requires explanation; mention has been made in the engine section of various forms of hot tube ignition, and as these have been described individually, they will be ignored here and only electric ignition will be dealt with.

There are two great sub-divisions of electric ignition, high tension and low tension. The high-tension system depends for its igniting properties on a jump spark, crossing a spark gap inside the cylinder, while the spark of the low-tension system is produced by suddenly interrupting a current flowing between contacts inside the cylinder.

The high-tension system will be dealt with first, and a synopsis of the accessory fittings used in connection therewith is appended. First there is the accumulator, from which the electricity is obtained, then an induction coil or coils to convert the low-tension current provided by the battery into high-tension current, a sparking plug to conduct the current to the spark gap inside the cylinder, and finally the various means adopted to so time the flow of current to the coil or coils that a spark is obtained at the required moment in the cylinder.

Then, again, a sub-division is necessary to deal with the magneto, a device designed to generate electricity and so to dispense with the accumulator.

Before proceeding further, an explanation of a few electrical terms that are in constant use is necessary.

The *volt* is the unit of electrical pressure, corresponding more or less to the pressure of steam in a boiler or steam engine; it is usually denoted by the symbol V.

The *ohm*, written R, is the unit of resistance to the flow of an electric current. An ordinary telegraph wire has a resistance of roughly one ohm per 100 yards.

The *ampère*, denoted by the letter A, is the unit current, corresponding to so many gallons of water per hour. The strength of the current in any circuit varies directly as the voltage and inversely as the resistance, and an ampère is the current that one volt can send through a resistance of one ohm. The above is known as "Ohm's law," and may be expressed symbolically as $C = \frac{V}{R}$ or $V = CR$. By aid of this formula, it is possible to calculate either voltage, current, or resistance if the other two are known. Thus, if we wish to send a current of five ampères through a resistance of half an ohm, we have :—

$$V = 5 \times \tfrac{1}{2} = 2\tfrac{1}{2} \text{ volts.}$$

To give some idea of the magnitude of the quantities dealt with in ignition circuits, it may be mentioned that the resistance of an averaged sized accumulator is about 0.2 ohm, and that the current taken by an induction coil is in the neighbourhood of 8 ampères. The voltage at the high-tension terminal of a coil is about 30,000 or 40,000 volts, sometimes even more. It requires 70,000 volts to produce a spark an inch long.

The *ampère-hour* is the unit of quantity of electricity and is applied to accumulators to express their capacity. For instance, a 20a.h. accumulator means that a flow of 1 ampère can be obtained for 20 hours—or any other two multiples, provided that the ampèreage is not so high as to buckle the plates.

Electro-chemical Sources of Current.

There are two distinct classes of electric battery from which current may be obtained, namely primary batteries, and secondary batteries or accumulators. The first class consists simply of two electrodes and of certain chemicals, which, when the electrodes are joined together electrically, start various chemical actions, with the result that the chemical energy given up in the process reappears as electrical energy. After a time the chemicals in the cells become changed and inactive, and the battery is then only of use after recharging, and it is here that the difference between a primary battery and an accumulator becomes apparent, for the latter, though it converts chemical into electrical energy in precisely the same way, is reversible in its action. Thus if a current is passed through an exhausted accumulator in the reverse direction to that in which the accumulator gave out its current, the electrical energy will be converted into chemical energy, and the plates and electrolyte of the accumulator will return to the same chemical condition as existed before the cell was discharged.

Dry Batteries.

Primary batteries for ignition purposes are made in what is called the "dry" form simply to avoid the mess made by liquid slopping out from the ordinary type, and for convenience of storing, for dry cells can be put in any position without injury. There are several different makes of dry batteries, but all consist of an active electrode of zinc (to which the negative terminal is connected), in contact with a mass of plaster of Paris soaked in a solution of sal ammoniac or zinc sulphate, which serves as the electrolyte, and a positive or non-active electrode, usually of carbon, to which is connected the positive terminal of the cell, and this electrode is usually buried in a mass of manganese dioxide, or other "depolariser," according to the chemicals employed in the cell. When the terminals of such a cell are joined together, an electric current is generated, owing to the zinc dissolving in the electrolyte—the reason of this is beyond the scope of the present work. Hydrogen gas, due to electrolysis of the electrolyte, is formed, and collects at the positive electrode, and, gas being an insulator, it would quickly stop the current, which is technically known as "polarising," were it not for the absorbing or "depolarising" action of the carbon or other depolariser surrounding the electrode.

As a matter of fact, more or less polarisation will always set in if any attempt is made to take a steady current from a dry battery for any length of time, and for this reason such a cell is better suited for a single-cylinder engine than for, say, a six-cylinder motor, where the current is required almost continuously.

A dry battery only gives about 1-.2 volts, and has a high internal resistance, usually about 4 ohms in an ordinary sized cell, and for this reason six cells should be coupled in series to give as much current as an accumulator. The chief use of dry cells is as a standby in case the accumulator runs down out at sea, for a cell, stored in a dry place, will keep for months.

Accumulators.

Though the construction of accumulators varies considerably in detail, practically all cells follow the same general principles, a lead frame, usually a grid, serving to support the active material of the plates. The positive plates are coated with red lead, and the negative with minium, a lower oxide of the same metal. The plates being immersed in a dilute solution of sulphuric acid, both positive and negative may be considered as being reduced to lead sulphate, the acid being thereby weakened. This accounts for the drop in specific gravity of the acid which, in a fully-charged cell, should be about 1,120 to 1,200, as read by means of a densimeter. On charging a cell the positive plates again become lead oxide, while the negative plates are reduced to spongy lead, the sulphur previously taken up being returned to the electrolyte and increasing the specific gravity.

These chemical actions change the volume of the paste in the grids, and it is when these changes take place too rapidly that buckling of the plates occurs, owing to the sudden strains set up; which accounts for the necessity of neither charging nor discharging cells too rapidly. Concerning the rate of discharge, little need be said, since the capacity of cells is made suitable to supply the current taken by the coils, and, beyond avoiding short-circuiting his cells, the user need not consider the matter. The charging rate is, however, a point that generally has to be settled by the motorist, and a simple rule is therefore appended to enable the necessary current for any cell to be determined—*allow a current of six amperes per square foot of positive plate surface.*

This rule will give a moderately fast charging rate, which might with some cells be exceeded by as much as 50 per cent., but by always using this strength of current the life of the accumulator will be considerably lengthened. In making the calculation *both* sides of *each* positive plate must be taken into account, but the plates of *one* cell *only*, not the total number of positive plates in the two cells, going to make up a four-volt accumulator.

Assume the plates of a cell measure 5in. by 7in., and that there are three positive plates in

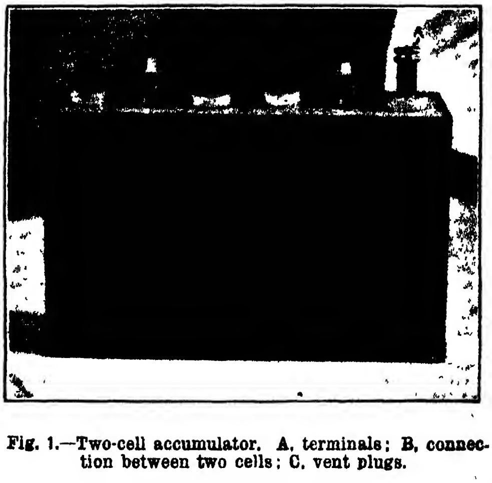


Fig. 1.—Two-cell accumulator. A, terminals; B, connection between two cells; C, vent plugs.

each cell, then the correct charging current will be :—

$$\frac{5 \times 7 \times 2 \times 3}{144} \times 6 = 8.75 \text{ amperes.}$$

Usually the most convenient way of charging is off an ordinary electric light circuit, using the

lamps as resistances. To ascertain the correct number and arrangement of lamps to be adopted, the voltage of the circuit must be known, and also the candle-power of the lamps used.

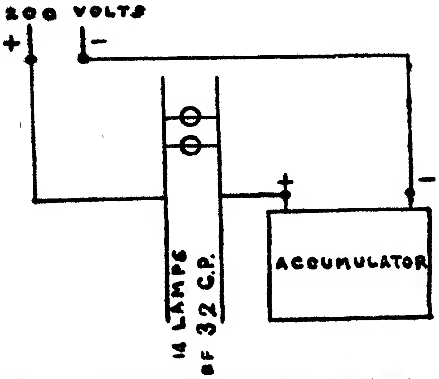


Fig. 2.—Connections for accumulator charging from lighting mains.

To find the current through any lamp, the candle-power of the lamp must be divided by the voltage and multiplied by 4. The reason for this is that a carbon filament lamp takes 4 *watts* per candle-power (this figure is considerably less in the special filament lamps), and a *watt* is the unit of power, being equal to C × V. Suppose, for example, a number of 16 candle-power lamps are available, and that the pressure of the circuit is 200 volts, then the current taken by each lamp will be $\frac{16 \times 4}{200} = 0.32$ ampère, so that to obtain a current of 8.75 ampères it would be necessary to use $\frac{8.75}{0.32} = 27$ lamps side by side, or "in parallel." This is obviously an inconvenient arrangement, and it would probably be simpler to use half the number of 32 candle-power lamps (say 14), which would, of course, give the same total resistance, or to use an altogether smaller current (which will do no harm whatever to the accumulator), and take a longer time to charge the cells. Assuming, however, that the full current is used, it would possibly be unsafe to take it from a small branch circuit in the house, owing to the wires installed not being thick enough to carry the current, and it is better to make the connections, if possible, at the main, or, failing that, on the most heavily-wired branch circuit in the house. It is not in any case advisable for anyone quite ignorant of electrical matters to make his own arrangements without help; but any wireman would do all that is required.

It is essential that the positive pole (or terminal) of the accumulator be connected, through the lamps, to the positive of the house circuit, and to this end the polarity of both must be ascertained. In the case of the accumulator this presents no difficulty, since the positive plates are chocolate in colour, and the negative grey; in addition to this, it is a practically invariable practice to paint the positive terminal red.

To find the polarity of the house circuit, wires from the two terminals may be dipped in a glass of acidulated water, when bubbles of gas will be seen to ascend from the ends of the wires, a considerably greater volume of gas coming from one than from the other. The wire from which most bubbles rise is the negative. Another method of finding the polarity of the circuit is by the use of pole-finding paper, obtainable from most electricians, which, if damped and held across the terminals, will develop a red stain at the negative pole.

There are several ways of telling if an accumulator is fully charged, perhaps the most reliable indication being the escape of a great deal of gas from the electrolyte or acid. The specific gravity of the acid, as given by a densimeter, is also a good method if the acid is of exactly correct strength, but a more reliable indicator is the ordinary voltmeter, which should read about 2.3 volts per cell on a fully-charged battery. Cells should never be discharged below 1.8 volt, or there is a tendency for a white, insoluble form of lead sulphate to form on the plates, which, being a non-conductor of electricity, decreases the capacity of the cell. The remedy for this trouble (known as "sulphating") is prolonged over-charging, and if this is unsuccessful, the accumulator must be taken down and the plates scraped.

It will occasionally be found necessary to add a little distilled water to the cells to make up for evaporation, and care should always be taken to keep the plates entirely covered.

The Induction Coil.

It is impossible to give a really adequate description of an induction coil without going rather deeply into the laws of electro-magnetic induction, and as an enunciation of these must presuppose a sound, all-round knowledge of electricity and magnetism, an explanation of these phenomena is obviously outside the province of the present work. It must, therefore, be taken for granted that, given two concentric coils of insulated wire, if a current of electricity be suddenly passed through one coil, or if a steady current in that coil be interrupted, a momentary current will be induced in the second coil. The strength of this secondary or induced current varies directly as the strength of the current (whether started or interrupted) in the primary coil, and also on the "suddenness" of the contact or interruption of the primary current; or, more correctly, the secondary current varies directly as the rate of change of current in the

primary. The inductive effect is still further increased by the presence of a soft iron core inside the coils.

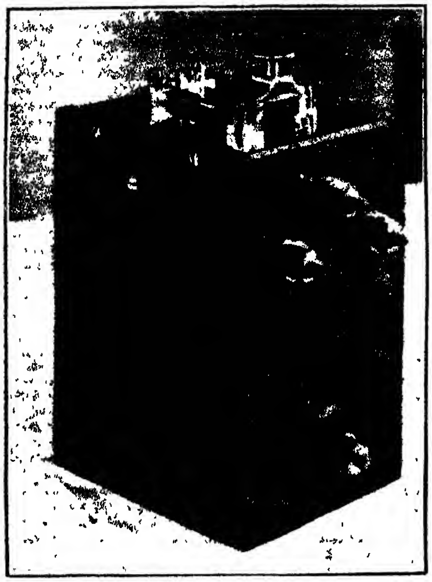


Fig. 3.—Induction coil. On top is the trembler, the upper terminal is a separate earth connection for the secondary, left-hand terminal to + of accumulator, right-hand one to wipe contact blade; bottom terminal is H.T. to sparking plug.

The exact meaning of the electrical units, the volt and ampère, has already been explained, so that the reader should have no difficulty in understanding the following law, which has a most important bearing on the subject of induction coils :—

The ratio between the voltages in the primary and secondary windings varies directly as the ratio of the number of turns of wire in the primary and secondary. It should also be noted that the ratio of the strength of currents in the primary varies inversely as the ratio of the number of turns, though this is not of so much importance so far as the question of ignition is concerned.

An example will make the matter clearer. Suppose there are two coils of wire, one of 10 turns and the other of 1,000 turns, wound concentrically, and that a current of 10 ampères at a pressure of 10 volts is passing through the shorter coil, the primary; then, if this current is suddenly interrupted, a momentary current of $\frac{10}{1000} = \frac{1}{100}$ ampères will be induced in the secondary, but at a pressure of $10 \times 1{,}000 = 10{,}000$ volts. Now the function of an induction coil is to convert the low-tension current supplied by the accumulator into a high-tension current, capable of jumping across the spark gap of a sparking plug, and this result is achieved by making use of the physical laws mentioned above. The coil as a whole consists of a bundle of soft iron wires forming the core (a solid iron core would become excessively heated by eddy currents, the nature of which need not be explained here), over which is placed a thick layer of insulation, usually a vulcanite tube. On this is wound the primary coil, consisting of two or three layers of thick wire, carefully insulated—with silk in the best coils and with cotton in the cheaper makes—to carry the heavy low-tension current supplied by the accumulator; then comes a layer of very highly insulating material, usually vulcanite or vulcanised fibre, and over this is wound the secondary coil, consisting of many thousands of turns of very fine, silk insulated wire. From what has been said it is easy to see that if an intermittent current be sent through the primary coil by alternately connecting and disconnecting its ends with the terminals of an accumulator, there will be very high voltage, or high tension, currents induced in the secondary winding, and if one end of this winding be connected to "earth," that is, to the engine frame, and the other end to the sparking plug terminal, a spark will be obtained, and it only remains to break or make the current in the primary circuit at such a moment that the secondary spark will be produced in the cylinder just when it is desired to fire the charge. In the older forms of coil this was effected by the familiar make-and-break contact on the half-speed shaft of the engine, which simply produced a single spark, and, incidentally, wasted a great deal of current.

The modern tendency is to fit a contact maker or wipe contact on the engine camshaft, which allows the current to flow for quite an appreciable time, and to obtain a series of excessively rapid interruptions of the primary current by means of a "trembler" attached to the coil. The trembler consists of a flat blade of springy steel, or in some cases of two or more such blades, carrying a soft iron head or "armature" set about an eighth of an inch off the end of the iron wire core of the coil. This blade is connected to one end of the primary coil, and the primary current passes through it by way of a contact screw, which can be adjusted to make contact more or less firmly with the blade. When the primary current passes through the coil, the iron wire core becomes strongly magnetised and attracts the iron armature of the trembler; the armature accordingly moves towards the core, and, in doing so, breaks the contact between the contact screw and the trembler blade, thus stopping the primary current. Directly this occurs, the iron core of the coil ceases to be a magnet, the armature flies back, and the primary circuit is again made, when the armature is once more attracted, and so on.

By using trembler blades with a very short period of vibration, and by careful adjustment of the contact screw, an extremely rapid series of sparks is obtained in place of a single spark, and

this stream is a far more efficient means of igniting the charge than is the single spark. Quite apart from the fact that, there being a number of sparks, one of them is sure to ignite the charge, even if one of the early ones fails to do so, the extremely rapid sparks are unaffected by the presence of conducting matter, such as carbon, on the sparking plug, and will continue to pass when the plug is so dirty that a single make-and-break coil would expend all its secondary current in leakage. This is due to what is known as "skin effect" in high frequency currents, meaning that the passage of a rapidly alternating current through a conductor meets with far more resistance than does a direct current, i.e., a current moving in one direction only.

From this the importance of having the trembler adjusted to give the most rapid interruptions possible may be readily understood, and it is this adjustment that one so often sees being made on a coil. A practised ear can detect by the note given out by the trembler—it should be a deep buzz—whether the adjustment is correct or not; but anyone not well enough up in the subject for this should adjust the trembler while the engine is running, the contact screw being turned very slowly first one way and then the other till the best result is obtained, when it should be locked in position by means of the lock-nut always provided, care being taken in doing so that the screw itself is not shifted. Usually it is correct to get the highest note possible out of the trembler; there is no fear of shock while making the adjustment. There is always a spark formed between the contact points of the trembler blade and the contact screw, and these points must therefore be of some non-oxidizable metal, otherwise they would quickly burn away and their contact surfaces become dirty and no longer make good contact. In all good coils platinum contact points are provided, or as platinum is a rather soft metal, platinum-iridium is sometimes used; cheap coils with German silver contacts should never be accepted on any account.

There is one part of a coil of which as yet, to avoid confusion, no mention has been made; this is the condenser, which consists of layers of tinfoil separated from each other by layers of very thin paper soaked in paraffin wax to obtain perfect insulation, the tinfoil sheets being divided into two sets arranged in alternate layers, all the sheets of each set being connected together exactly like the positive and negative plates of an accumulator. The condenser thus has two terminals, and it is connected across the trembler on the coil, one terminal going to the trembler blade, the other to the contact screw.

The object of the condenser is to still further intensify the current in the primary circuit, by, so to speak, sucking an overdose of current into the coil from the accumulator when contact is made and ejecting the surplus again when contact is broken. The ability of the condenser to absorb current is technically known as its "capacity," and depends on the size and number of the tinfoil sheets; these have to be so adjusted in practice that the "capacity" of the condenser suits the coil—its "inductance," as it should be called—as a certain condition known as "resonance," which should exist between them to give the best results, depends on the ratio of the inductance and capacity of the coil and the condenser.

Usually the coil and its condenser are put in a stout wooden box and fixed firmly in position by filling the box up with paraffin wax with an ebonite plate to give a neat finish and to carry the trembler gear. It has already been mentioned that one end of the secondary coil has to be "earthed," and it is usual, instead of providing a second terminal for this, to connect it to one end of the primary coil, this being brought to the terminal on the coil marked "M," or "masse" in French coils. This terminal has to be connected to the blade of the low-tension contact maker on the engine. The other end of the primary winding is connected to the accumulator (diagrams of connections appear on another page), and the remaining end of the secondary coil is taken to a highly insulated terminal which is connected to the sparking plug of the engine.

There is, by the way, another method of connecting up the secondary winding which is adopted in the Lodge coil. Both ends are insulated and connected to the inner coatings of two Leyden jars or other form of condenser; the outer coating of one jar is earthed, and the other connected to the engine sparking plug, whereby a very high frequency indeed is obtained.

Perfect insulation is, of course, of the highest importance in a coil, and a breakdown of the insulation in any part of the coil itself entails rewinding, which is very expensive and usually never gives quite such a good result as the original coil. Some of the very best coils have the secondary winding made as a number of flat coils wound on ebonite spools, strung on over the primary and connected in series. Besides very much reducing the strains to which the insulation is subjected, this arrangement has the advantage that if one section of the coil should break down, it can be replaced without affecting the rest of the coil.

Finally, let it be noted that in whatever part of the engine or its accessories economy is exercised, a cheap coil should never be purchased under any circumstances whatever. Nothing can compensate for a coil that can only give a feeble spark, while a breakdown in the insulation must inevitably mean that the boat will be laid up while repairs are being executed by the makers of the coil (or by an electrical engineer), for it is not a job that should be attempted by the amateur. With a really first-class coil a breakdown is not in the least likely to occur except through careless or unfair treatment. For instance, a coil must never be mounted in close proximity to the exhaust pipe, or the paraffin wax insulation may soften, nor should a 4-volt coil under any circumstances be used in conjunction with a 6-volt battery.

Low-tension Contact Makers.

Accumulators and coils have now been dealt with, and the function of a low-tension contact maker has been indicated, so it need not be repeated here. The contact maker, whether of the "wipe" or "make-and-break" type, which will be differentiated later, consists essentially of a rotating arm, keyed to the half-time shaft of the engine, and, therefore, "earthed," making contact with one or more insulated contact arms or segments mounted on any convenient form of bush, and each connected to an induction coil, as described in the "Wiring Up" section. The rotating arm, as it comes in contact with each of these in turn, connects it, and, therefore, the coil, to earth, thus completing the primary circuit, and it is only necessary to set this arm in such a position on the camshaft that each connection to a coil is completed at the moment when a spark is required in the cylinder to which that particular coil is connected.

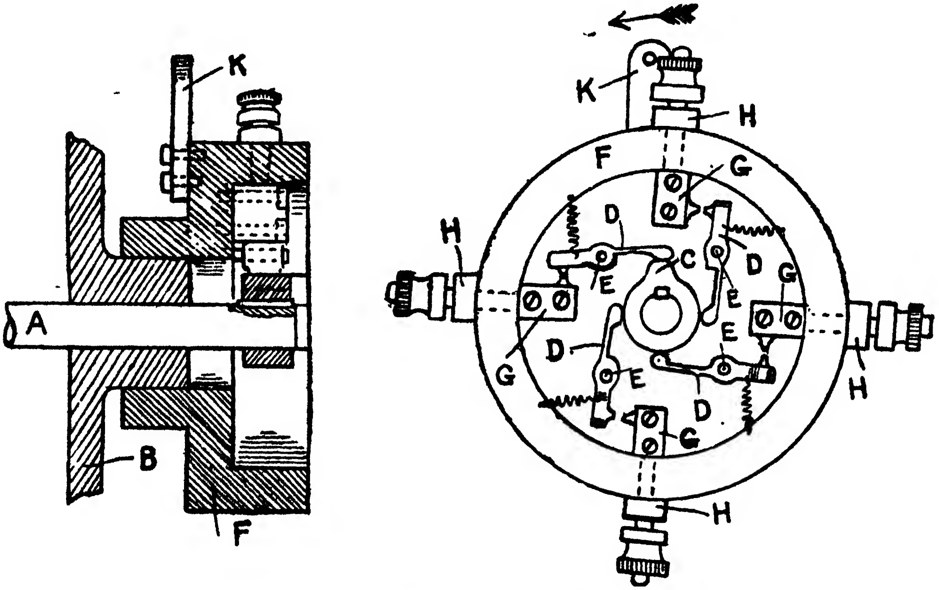


Fig. 4.—Low-tension make-and-break.

Fig. 4 clearly shows the principle of a make-and-break for a four-cylinder engine. (A) is the engine camshaft projecting through the engine casing (B). A cam (C) is keyed to this shaft, and engages with the contact arms (D) as shown. These arms are pivoted about the pins (E), which are secured in the back of the ebonite body (F) of the make-and-break. The contact pieces (G) with which the arms (D) engage are also screwed to F, through which they pass to the terminals (H) intended for connection to the induction coils. The way in which the little arms (D) are employed is sufficiently obvious from the drawing, and it will be noted that small springs hold them out of engagement when clear of the cam; the portion of the arms shown very narrow would in practice be made of springy steel to allow for wear in the contact points, which, by the way, should be of platinum, as in the trembler of an induction coil. The lever attached to the body of the make-and-break would be connected by a Bowden wire or a system of levers and rods to a hand lever on the control board; it is, of course, intended to rock the portion F and its fitting on the boss of the crank-case (B) to advance or retard the ignition as required. Suppose, for example, the camshaft is rotating clockwise in the illustration; then, if the lever (K) be moved in the direction indicated by the arrow, the arms (D) will come earlier into contact with the cam (C), thus advancing the ignition.

It must not be supposed that the drawing is intended to represent any existing type of make-and-break; it is purely diagrammatic, and would in practice be a very poor design, for the short length of the springs in the arms (D) would soon cause them to snap, and the absence of any metal bush to F would cause this part to wear very rapidly, and it would quickly become eccentric to the camshaft, causing the arms (D) to miss their contact pieces. The chief desiderata for a good make-and-break are—high insulation, protection from damp, strong

mechanical design, good electrical contact, and a design of cam and contact arm that will not jamb should the direction of running of the motor be reversed, as by a back-fire.

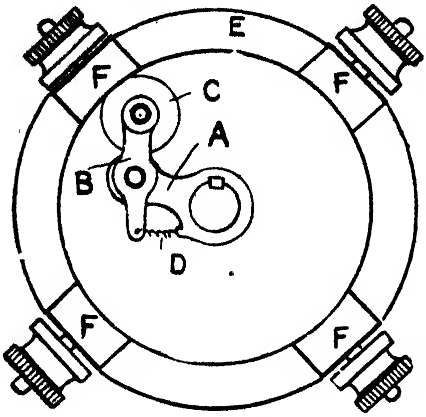


Fig. 5.—L.T. wipe contact diagram.

A Wipe Contact.

The requirements and principles of construction of a wipe contact form of make-and-break are exactly the same, and this type certainly enjoys the advantage of extreme simplicity, while with a good design there is no difficulty experienced in maintaining good contact. The diagram (Fig. 5) shows the end elevation of the wipe contact. The arm (A) is keyed to the engine camshaft, and rotates with it, while the contact arm (B) is pivoted at the end of A, and has its roller (C) kept in contact with the metal segments of the commutator by means of the spring (D). As in the make-and-break type, the commutator (E) is an insulator, and forms the body of the wipe contact, in which are metal segments (F) connected to the terminals. An advance and retard lever is, of course, attached to E in the ordinary way.

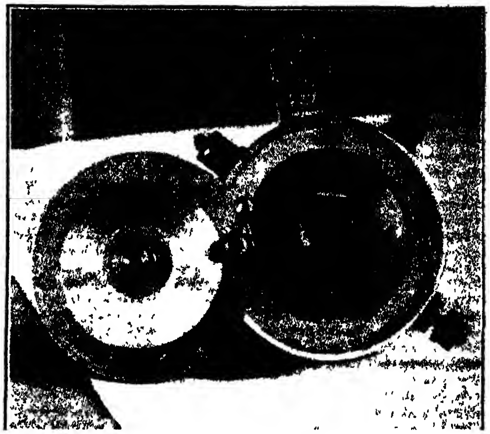


Fig. 6.—A good type of L.T. wipe contact.

High-tension Distributors.

The use of a wipe contact in conjunction with a separate coil for each cylinder has already been dealt with, and in the early days of multicylinder engines this was the almost universal practice. But with the advent of the magneto a high-tension distributor, that is to say, a device for distributing high-tension current from a single source of supply to a number of cylinders, in turn became a necessity, and it was only a corollary to apply the same principle to distribute the current generated in an induction coil.

A distributor consists essentially of a commutator mounted on a half-speed shaft, having as many segments as there are cylinders, and having all these segments "earthed." A wipe contact arm insulated, and connected to the "M" terminal of the coil, completes the primary circuit whenever a metal segment is passing under it, and it is only necessary to set the position of this contact arm so that these contacts are made when the engine is in the firing position. Then there must be a high-tension distributing arm mounted on the half-speed shaft, but very highly insulated from it, and connected by any convenient form of sliding contact to the high-tension terminal of the coil; this arm obviously receives the high-tension current at the same moment that the low-tension circuit is completed, and if terminals, leading to the sparking plugs, are spaced round this arm so that they receive the high-tension current from it in turn, the requirements of a distributor are fulfilled.

There are a variety of patterns of distributors on the market, good, bad, and indifferent, and it is rather curious to note what a complete absence of electrical knowledge is shown in some of the designs. Utterly inadequate contact is frequently to be found in the low-tension circuit, and the high-tension terminals will often be found to be insufficiently insulated. Except in the case of one excellent design, which is completely enclosed with its coil in a box, all high-tension distributors are, from their nature, placed in more or less exposed positions, with the result that insulation, which would be quite sufficient in a coil, where everything is shut in, is not good enough when damp can collect on its surface.

It was lack of appreciation of these two points that made some of the earlier distributors unsatisfactory, and which made the whole system

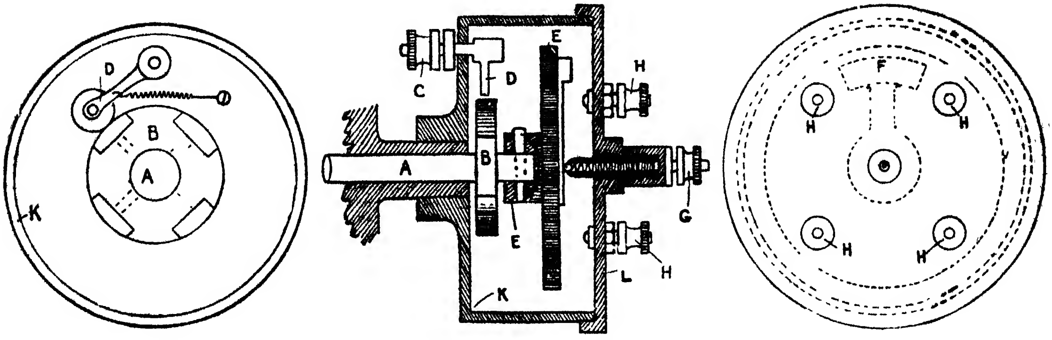


Fig. 7.

fall rather into disrepute with an unthinking public, but with rational design there is everything to be said in favour of the high-tension distributor.

A typical design is shown in Fig. 7. A is the half-speed shaft, carrying the commutator (B)—in this case for a four-cylinder engine. The terminal (C) is connected to the induction coil and forms a pivot for the wipe contact arm (D), which completes the primary circuit. On the end of the half-speed shaft is an insulating piece (E), which carries the high-tension distributing arm (F). G is a terminal connected to the high-tension terminal of the coil, and the current is passed to the distributing arm (F) by means of the ball and spring contact as indicated.

The high-tension leads to the engine cylinders are connected to the terminals (H, H), also in many cases made with ball contacts, and the arm (F) rotating with the half-speed shaft, passes the current to each in turn. The whole is enclosed in an ebonite case (K) mounted on the boss of the shaft bearing, and the end plate (L), also of ebonite, is fixed in such a position that

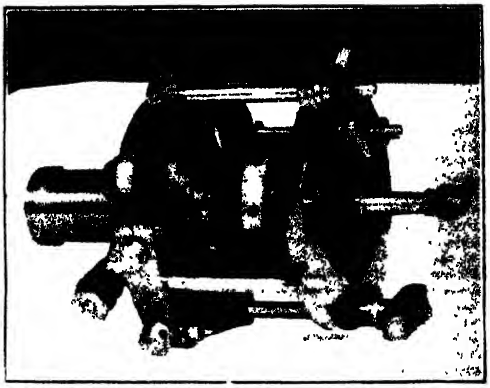


Fig. 8.—H.T. distributor with outer case, carrying the terminals for connection to plugs, removed.

Fig. 9.—H.T. distributor in pieces. A, H.T. contact to distributing arm; B, H.T. distributing arm; C, L.T. contact cams; E, E, L. T. contacts in parallel to ensure current passing even if one is dirty; D, D, tappets on contact levers.

the distributing arm always passes one of the terminals (H) at the same moment that D is connected to earth through one of the segments of B. To vary the timing the whole of the case (K), with its cover (L), can be rocked through a certain angle, the high and low-tension contacts remaining synchronised with each other.

In favour of the high-tension distributor one may say that it is much cheaper than having to buy several coils, and that there is only one trembler to keep in order—two very important considerations. There is only one objection to be offered to its use now that there are several good makes to choose from, namely that if the coil fails for any reason the engine must stop. But even on this point the high-tension distributor has the advantage over the separate coil system so far as cost is concerned, for it is cheaper to carry two coils, one in use and one spare, than to have four or perhaps six coils all in use simultaneously, while there is a considerable saving in weight and space.

Sparking Plugs.

The sparking plug is probably the most familiar of all the necessary accessories of the motor, for it is the one that requires, perhaps, the most attention, and, being very easily accessible, it is one of the first parts with which the novice is likely to become acquainted. There are an endless number of patterns of plug, but the essential parts are as follow :—An insulator carrying the high-tension wire in its centre, a metal socket screwing into the cylinder head or combustion chamber of the engine, and a cap which screws into the socket, gripping a shoulder on the insulator between the socket and cap.

The insulator may be either of porcelain or mica, some makers preferring one and some the other. Mica is a better insulator, but as it consists of very thin layers pressed together there is always the danger that, should one layer crack, a spark will be able to jump across. Porcelain, on the other hand, is liable to crack if unequally heated, and, being brittle, is more likely to be damaged by a chance blow, so that neither material has any undisputed advantage over the other.

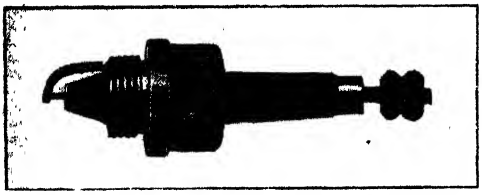


Fig. 10.—An E.I.C. mica plug for use with a coil.

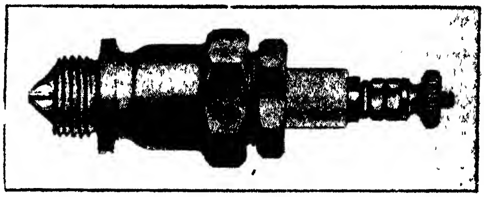


Fig. 11.—A Simms porcelain plug for use with a magneto.

Assuming that the best material, whatever its kind, is used, what really differentiates a good plug from a bad one is the extent to which it will stand sooting up without stopping the passage of the spark. Plugs with a very short path along the surface of the insulation from the insulated wire to the outer metal part should be avoided, as, once a carbon deposit is formed, the electricity only has a short path to travel to "earth," and such a plug would fail long before another with its insulation arranged on the "petticoat" principle familiar on the insulators on an ordinary telegraph pole. The surface of the insulation should be accessible to the bristles of a tooth-brush, which, soaked in petrol, will be found the handiest means of cleaning a plug. Apart from the packing nut, which may occasionally require to be tightened, the only adjustment required on a plug is the length of the spark gap, which, by rule of thumb, may be taken as the thickness of a worn threepenny bit or of a stout thumb-nail. Some makes of plugs have a flimsy piece of wire bent over from the socket to meet the central wire, or sometimes the central wire is bent towards the socket. Both these types should be avoided, as a long fine wire sooner or later gets bent or broken.

A magneto plug, which, by the way, usually has several spark gaps, should have a rather shorter gap. The object of the several gaps is to compensate for wasting of metal by burning away, owing to the excessive heat of the magneto spark; if one gap happens to be a little shorter than the other, the spark will, of course, pass at that gap until the burning of the points lengthens it, when the spark will shift to another position, and so on. The choice of several paths for the spark is obtained in a variety of ways, either by flattening out the end of the high-tension wire to a mushroom shape with little saw-teeth round the edge, or, to take another example, by putting a plate over the end of the screw socket, the plate being perforated to accommodate the high-tension wire which is brought through from the terminal of the sparking plug.

Switches.

But little need be said about switches, for their function of breaking the circuit requires no explanation, and, except for the old tumbler type so familiar in electric light installations in private houses, the almost universal type is the simple single spring lever pressing on metal studs, one in the "off" position and insulated, the other provided with a terminal for making required connections. The pivot of the lever is also, of course, provided with a terminal.

The two-way switch for use with two batteries is almost as simple; assuming the switch is placed between the batteries and the coil, the terminal at the pivot of the lever is connected to the "P" terminal of the coil, while the studs are connected to the respective batteries (see Fig. 12).

The points of a good switch are that it should be highly insulated and efficiently protected from wet. A small cylindrical ebonite casing is most commonly fitted, and is quite satisfactory. The remaining desideratum is that the switch should have a good stiff spring, not only to ensure good electrical contact, but to prevent the possibility of vibration shaking the switch out of contact.

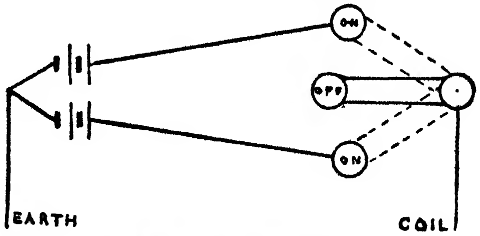


Fig. 12.—A two-way switch.

Wiring Up.

The component parts of the ignition circuit having been individually described, the connecting up of the system has to be considered. Broadly speaking, the subject may be dealt with under two distinct heads, high tension and low tension. The high-tension system again splits up into three sub-heads, accumulator and separate coils for each cylinder, accumulator and single coil, with high-tension distributor, and, lastly, high-tension magneto, while the low-tension system is divided into two sub-heads, accumulator and solenoid, and low-tension magneto. For clearness, and to enable the reader to get a comprehensive idea of the whole question, the various systems are here collected in tabular form, and will be dealt with in the order in which they appear :—

HIGH TENSION.	LOW TENSION.
Accumulator and separate coils.	Accumulator and solenoid.
Accumulator and coil and H.T. distributor.	Magneto.
Magneto.	

Accumulator and Separate Coils.

Whatever the number of cylinders, the following connections are required with an accumulator and separate coil for each cylinder. The accumulator positive is connected to the "P" terminal of each coil, the accumulator negative is connected to earth, the "M" terminal of each coil is connected to one of the contact blades of the low-tension wipe contact (or make-and-break, as the case may be), and the high-tension terminal of each coil is connected to a sparking plug. The passage of the current from the accumulator is through the low-tension winding of the coil to the contact blades, thence to "earth," that is, to the engine frame, and back to the accumulator negative. In practice, a switch is inserted in the circuit (marked S in the diagrams) to enable the ignition to be shut off when necessary, and it is common practice to put this switch in circuit between the accumulator positive and the "P" terminals of the coils, though it might equally well be between the accumulator negative and the engine frame. Another alternative, and one that has to be adopted if it be desired to cut out one cylinder only and leave the others firing, is to put a switch between each "M" terminal on the coil and its contact blade, or in the branch connections from the accumulator positive.

When dealing with coils, it was mentioned that though the usual method is to "earth" one end of the secondary winding by connecting it to the primary winding, coils are occasionally made with a separate earth terminal for the secondary, and in this case, in addition to the connections given above, these terminals must all be connected to the engine frame. For the benefit of the complete novice, the cycle of operations in the ignition circuit may be briefly recapitulated. Assuming that the functions of coil, battery, and contact maker are already understood, it remains to show how (in a multi-cylinder engine) a spark is obtained at each cylinder in the correct order. Referring, for example, to the diagram for the four-cylinder engine (Fig. 18), and, taking it for granted for the moment that the correct order of firing is 1, 2, 4, 3, it will be noted that in the diagram the coil connected to No. 2 cylinder has its corresponding contact blade (A) in contact with the metal segment of the revolving wipe contact (which in all these diagrams is supposed to be revolving clockwise), and current is, therefore, passing through this coil only, producing a spark in No. 2 cylinder. When the engine has turned through another half-revolution, the

contact segment will have turned through a quarter of a revolution and will have put the coil of No. 4 cylinder into action; another half-turn of the motor brings the contact to No. 3 cylinder, and a further half-revolution back to No. 1, and so on. Dealing now with the diagrams in the order of the number of cylinders, the single-cylinder motor (Fig. 13) first claims attention, but little need be said about it, save that it would run equally well if the "M" terminal of the coil were connected to earth and if the accumulator negative were connected to the contact blade. This arrangement could not, however, be adopted on a multicylinder engine, since all the coils would come into action simultaneously every time a contact was made.

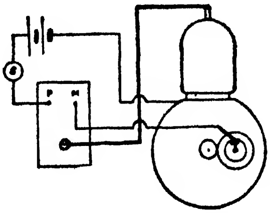


Fig. 13.

There are two distinct types of two-cylinder motors, depending on whether the cranks are in line or opposed. As a matter of fact, the type of motor with the cranks in line is not often met with, and it is much more usual to set the cranks opposite to each other. Diagrams for both these arrangements are given (Figs 14, 15), and it will be noticed that the only difference is in the setting of the contact blades relatively to each other. In the opposed crank engine they are at 90 degrees to each other on the camshaft, and in the other case they are set at opposite ends of a diameter of the contact disc. In these and in all subsequent diagrams in this section the setting of the cranks is indicated by a single line, also high-tension leads are shown in heavy lines to distinguish them from low-tension connections. It is scarcely necessary to say that the coils, whether for a two, three, four, or six-cylinder engine, cannot be connected up haphazard to any contact blade and any cylinder. Having found the two dead centres of the engine, and having marked these positions on the flywheel, and, further, having set the contact blades (with the advance spark lever set in about a mid-way position), so that they in turn make contact with the wipe disc (or make-and-break cam) when the engine is on its dead centres, it remains to find which piston is just on its firing stroke and to connect the coil of that cylinder to whichever contact blade happens to be in contact with the metal part of the wipe disc.

Having done this for one cylinder, turn the engine round to its next dead centre, and if another piston is in its firing position (which must be the case except in a two or three-cylinder motor), connect the coil of that cylinder to the contact blade now in contact, and so on for any number of cylinders.

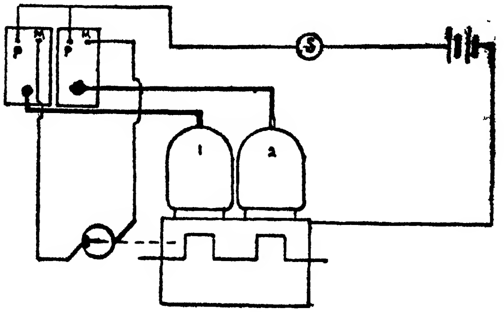


Fig. 14.

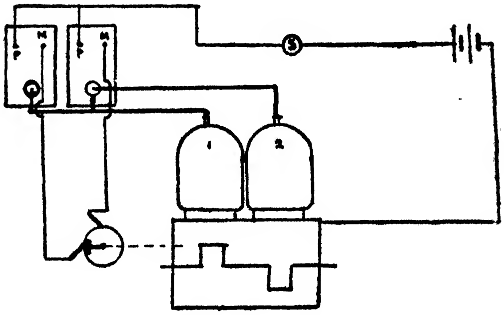


Fig. 15.

The simplest way to tell if a piston is just coming to its firing stroke is to watch the exhaust valve of that cylinder. If, when the piston is at the top of its stroke the exhaust cam is within a *quarter of a revolution* of engaging with the tappet rod, and if the cam moves *towards* the rod when the engine is turned in its usual direction of rotation, the piston is on the firing stroke. If, however, the exhaust cam moves *away* from the tappet the piston is on its suction stroke.

In cases where the cams cannot be easily seen, the simplest way of getting a piston to the beginning of its firing stroke is to turn the engine forwards until the exhaust valve of that cylinder begins to open, then turn the engine back half a revolution to bring this piston to the top of its stroke, when it will be in its firing position.

The inlet valve, if mechanically operated, forms an equally good indicator, since if the piston is just commencing the suction stroke, the valve will be opened as the engine is turned. By following these instructions carefully, no difficulty should be experienced.

Next to a single-cylinder engine, a three-cylinder motor presents the least difficulty, since its cylinders fire in regular order 1, 2, 3. The diagram (Fig. 16) shows No. 1 cylinder firing,

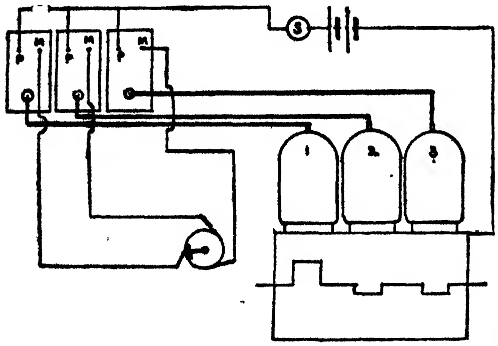


Fig. 16.

and it must be understood that the cranks are set at 120 degrees to each other. Suppose the direction of rotation of the engine is such that No. 1 crank-pin is moving downwards through the paper, then No. 2 crank will be slanting downwards through the paper and will have to turn through two-thirds of a revolution before it comes to its firing position. No. 3 crank is supposed to be pointing obliquely upwards, and will pass through its upper dead centre while No. 1 is on its power stroke, during the latter part of which No. 3 will be starting its suction stroke.

In a four-cylinder engine the two centre cranks are almost invariably placed side by side, as shown (Fig. 18), to give the best balance, and there is, of course, an explosion each half-revolution. In this case the cylinders evidently cannot fire in the order 1, 2, 3, 4, and the order must be so arranged that cylinders with cranks at 180 degrees must fire next to each other. Starting at No. 1, the order of firing may be

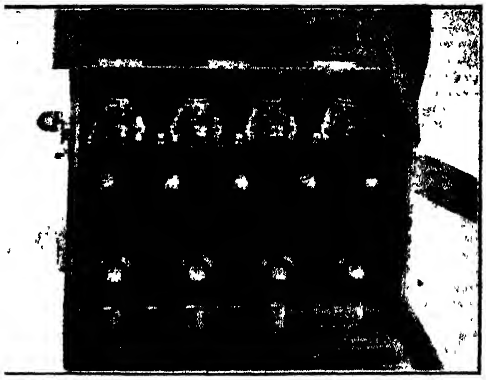


Fig. 17.—Four coils mounted together; the "P" terminals are all connected to a common terminal at the left-hand end.

either 1, 2, 4, 3, or 1, 3, 4, 2. In the diagram, connections are shown for the order 1, 2, 4, 3, and No. 2 cylinder is just firing.

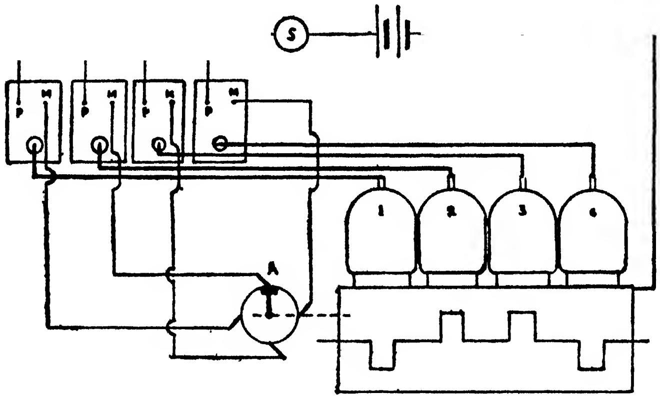


Fig. 18.

The order of firing of a six-cylinder engine (Fig. 19) is 1, 3, 5, 6, 4, 2, and the cranks, as in a three-cylinder motor, are set at 120 degrees, so that Nos. 1 and 6 are in line with each other, as also are Nos. 2 and 5 and Nos. 3 and 4. The engine, as shown, is firing on No. 1, and if No. 1 crank is moving away through the paper, cranks Nos. 3 and 4 must be considered as slanting obliquely *upwards*, while Nos. 2 and 5 are slanting downwards through the paper.

Exactly the same principles apply to an eight-cylinder engine, though this type is very rarely met with, except with cylinders set in a V, in which case a high-tension distributor is fitted.

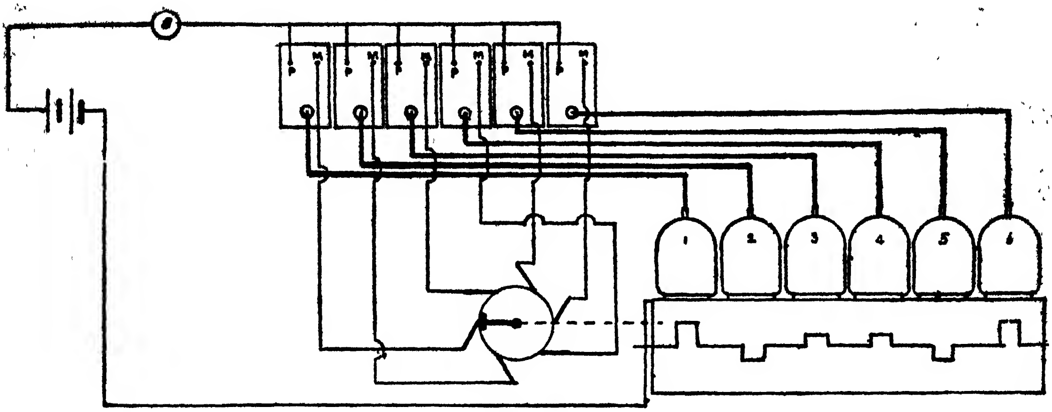


Fig. 19.

Accumulator and Coil with High-tension Distributor.

Though for a two-cylinder engine nothing would be gained by using a single coil and high-tension distributor, owing to the fact that the extra coil would cost very little more than the distributor, when an engine of three or more cylinders has to be considered a very considerable saving in cost, weight, and space is effected by the use of the high-tension distributor, and diagrams of connections for three, four, and six cylinders are given (Figs. 20, 21, and 22). In each case A is the half-speed shaft, to which is keyed the wipe contact disc, the metal segments of which are connected to earth through the shaft (A). The "M" terminal of the coil is connected to the contact blade (D), so that the four primary contacts (in the case of the four-cylinder engine) are obtained for each revolution of the camshaft, as already described when dealing with the principle of the distributor.

The high-tension distributing arm (B) is also keyed to the shaft (A), but is insulated from it, being, however, connected to the high-tension terminal of the coil by a rubbing contact; the distributing arm passes under the metal segments of the distributing drum (C), distributing the high-tension current to the cylinders, as shown.

The same remarks as to order of firing and methods of connecting up apply to the high-tension distributor as to the separate coils. The high-tension distributing drum and the low-tension wipe contact blade are, of course, mounted on the same rocker arm, and can be advanced

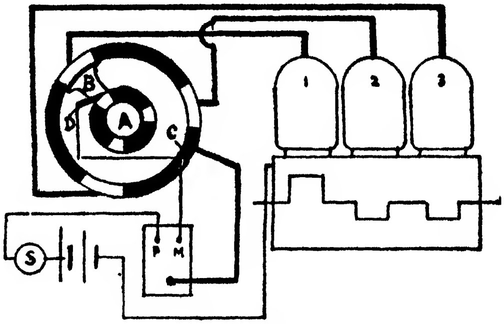


Fig. 20.

or retarded together, so that the high and low-tension circuits are always completed together. In all three of these diagrams, it should be noted that the blocked-in parts of the distributor represent insulation, the white segments being the metal; Figs. 20 and 22 show No. 1 cylinder firing; Fig. 21 shows No. 2 cylinder in the firing position.

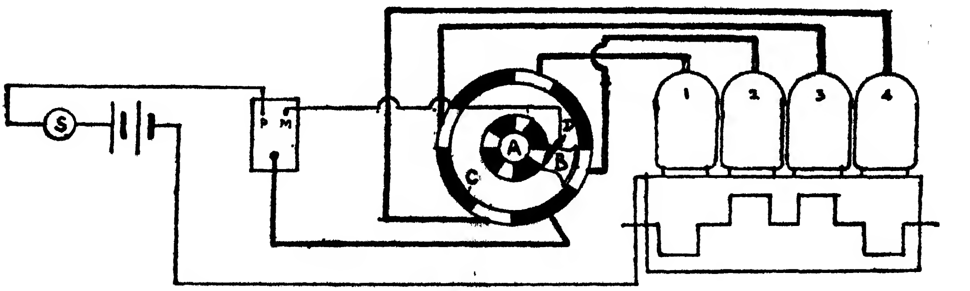


Fig. 21.

Mention was made a little way back of the eight-cylinder engine with cylinders set in a V, two pistons being connected to one crank. The crankshaft is precisely similar to that of an ordinary four-cylinder motor, and the two sets of cylinders may be regarded as two separate engines firing in the usual order—1, 2, 4, 3, but starting from opposite ends, and an explosion coming from each engine alternately. Fig. 22a shows the arrangement clearly, the circles indicating cylinders and the numerals inside them the order in which they fire. Taking the top row, and regarding it as a simple four-cylinder engine, the order of firing is 1, 3, 5, 7, which is the same thing as 1, 2, 4, 3 in a four-cylinder engine, while the bottom row fires 2, 4, 6, 8, which is the same as 1, 2, 4, 3 in the four-cylinder motor starting from the opposite end.

An explosion is thus obtained once every *quarter* of a revolution, and the low-tension contact and also the high-tension distributor would require eight contact points distributed evenly round a circumference and connected in order to the cylinders marked 1, 2, 3, 4, and so on.

Wiring Up Magnetos.

Exactly the same remarks and diagrams apply to wiring up a high-tension magneto, whether of the type having the secondary winding on the armature or having a separate induction coil supplied with current from the armature. In some patterns the high-tension distributing arm may be out of sight and not easily accessible, or, at any rate, it may not be easy to trace the connections from the distributor to the high-tension terminals of the magneto, so that there may be some difficulty in finding the order in which these terminals become "live."

Assuming that the magneto has already been mounted, and its armature, or shield, as the case may be, set correctly, relatively to the crankshaft, the high-tension terminals may be connected at random to the sparking plugs, which latter should be laid on the top of the cylinders with the spark gaps in view. The engine should then be turned round by hand, not rapidly, but with a quick jerk at each dead centre to ensure getting a spark, at the same time avoiding letting the engine turn any distance after the spark has occurred; it is sure to go a quarter of a revolution or so, and to avoid confusion it should be put back to the dead centre. An inspection of the positions of the valves and cams will show which cylinder is ready to fire, as already described, and the high-tension wire and plug, at which a spark has just appeared, can then be changed over to this cylinder and the process repeated for the remaining ones. Once set correctly the magneto high-tension terminals may be permanently marked 1, 2, 3, etc., corresponding to the cylinder to which each has to be connected so that future connections can be very easily made.

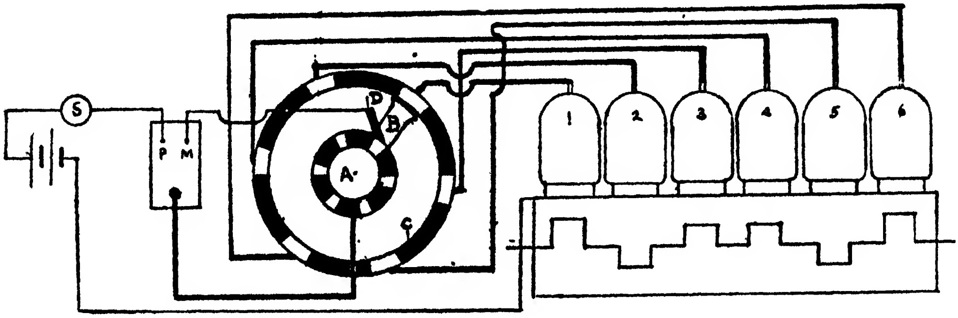


Fig. 22.

Low-tension Magnetos and Solenoid.

Connecting up for low-tension ignition, whether magneto or solenoid, presents no difficulties, nor is there any need to worry about timing, since this depends entirely upon cams on the half-speed shaft. In the case of a solenoid one terminal goes to the battery positive and the other to a bus bar, or insulated conductor, running alongside the engine, with branch connections and switches to each cylinder, while the battery negative is earthed. With a magneto there will probably only be one terminal,

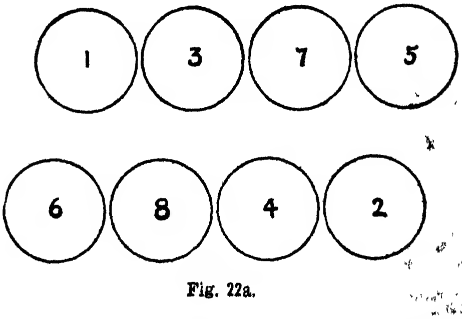


Fig. 22a.

the other end of the armature being earthed through the armature core, and this terminal is simply connected to the bus bar.

The Lodge Ignition.

The feature which distinguishes the system of ignition invented by Sir Oliver Lodge from the ordinary high-tension coil and accumulator ignition is that the spark is an oscillatory or high-frequency discharge from special condensers or Leyden jars. The discharge takes place so precipitously that it bursts down any obstruction in its path. The spark has also a different appearance to that from an ordinary H.T. coil, being of a fat, white-hot character with remarkable igniting properties, rendering it particularly suitable for gases of low calorific value. As a consequence of this, very low-speed engine running can be obtained, since a weak mixture is readily ignited by the spark, while very fast running is also rendered possible by a momentary spark being amply sufficient to fire the mixture. The Lodge ignition is quite unaffected by all the ordinary causes of short circuits, because there is such an impulsive rush of high-pressure current surging across the sparking plug gap that, even if the plug is flooded with oil or wet all over (both inside and out), the current still takes the direct route across the gap. There is no time for the current to choose an easier path. To put the matter scientifically, it is a very high-frequency discharge, and the "skin effect" causes any conductor to have enormous resistance, this accounting for the fact that very little shock is felt from a Lodge coil, though the voltage is as high as in any other coil.

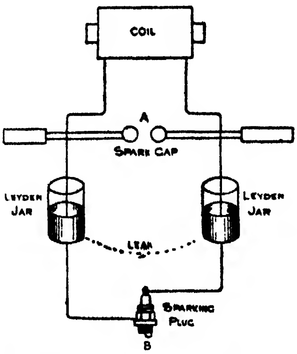


Fig. 23.—Diagrammatic view of igniter.

We will now proceed to give an explanation of the principle of the "B spark," as it is termed, and the diagram (Fig. 23) will show the general principle of the arrangement. The terminals of the coil are not connected to the sparking plug directly as usual, but are led to it through the intervention of a pair of coated insulators, or Leyden jars, with their outer coatings short-circuited by a leak or imperfect conductor, the object of which is to keep them always at the same potential, except at the instant of a sudden electric discharge. Accordingly there is no strain thrown upon the leads or the sparking plug, whose terminals remain at the same potential up to the last moment when the two jars are full and discharge at A. At this instant all the charge is liberated, and, with a rush of an oscillatory nature, the jars empty

Fig. 24.—Type D igniter.

themselves across A, inducing a high-frequency discharge through the sparking plug. No leak or imperfect conductor has time to exert any influence on the rush, owing, as already explained, to the phenomenon known as "skin effect."

The rush is so violent that not only is dirt in the path blown away, but the electric momentum overshoots the mark, and the jars are charged up in the reverse direction by the impetus; they then discharge again, and again are charged in the ordinary way, and so on many times, without the coil taking any further part in the action: its function is over when it has filled the jars to overflowing. The jar spark is a noisy, white-hot spark of extreme suddenness, all over in an extremely short period, and can be timed to occur with great accuracy.

In popular language, a discharge is brought about quite suddenly between points which, except during the rush, are completely inert, so that they might be handled with impunity, or placed under water, or clogged with dirt. But during the violence of the rush the dirt in the path is flung away, the water is burst through; the circuit is bound to be completed when the full discharge occurs at A. The A spark is, therefore, a pioneer spark, which precipitates the sudden rush and causes the B spark. The A spark is in the box under glass, so as to be easily open to inspection, and where it can be kept quite clean. The charge is prepared or generated by the coil, as usual, all the strain being thrown upon the clean gap at A, and directly this gap gives way, the whole accumulated contents of the jars are suddenly emptied or exploded without warning through the combustible mixture, the time of firing being accurately adjustable by the primary cam which regulates the charging action of the coil.

The Lodge igniter is made in two types:

types L and D. The former (Fig. 24) is used with a 6-volt. accumulator and has a single trembler and a reversing switch for equalising the wear of the platinums, and is particularly suitable for single-cylinder engines running on paraffin, benzol, etc. Type D (Fig. 25) is fitted with glass panels and has two tremblers, with a change-over switch and also a reversing switch (as can be seen through the front panel). It is suitable for the very highest speed engines of any number of cylinders. The essential parts of each type, however, are similar. The adjustable spark gap, seen on the top of each coil, serves as an indicator, but it has also another use : by opening out the gap, the intensity of the spark at the plug is increased and the points cleaned by all deposits being blown away. The Leyden jars, or high-tension condensers, are contained in the case and are made of special metal-coated glass. The coil itself calls for no special remarks, except that the iron core has taper ends, which cause the tremblers to work in a very strong magnetic field.

The wiring up is just the same as with an ordinary coil and accumulator; a high-tension distributor of the ordinary design being used with multi-cylinder engines, while ordinary sparking plugs are utilised. In fact, the only special part in the Lodge system is the igniter, which takes the place of the usual trembler coil.

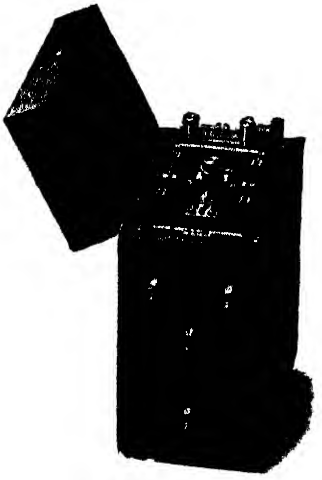


Fig. 25.—Type L Igniter.

High-tension Magnetos.

If the iron core of an induction coil were replaced by a permanent " bar " magnet, and if this magnet were *rapidly* withdrawn and replaced inside the primary winding, a current would be induced in this winding if its ends were joined together, and, to go a step further, if the strength of the permanent magnet were the same as the strength of the soft iron core when momentarily magnetised by the passage of the battery current through the primary winding, then the strength of the induced current in the primary, due to the withdrawal and replacement of the permanent magnet, would be the same as that supplied by the battery, neglecting certain losses which need not be dealt with here. Also a high-tension current would be induced in the secondary winding just as when a battery was used.

Thus it will be seen that if the magnet could be reciprocated extremely rapidly by the engine so that it moved inside the winding of the coil like a piston in a cylinder, the coil would generate its own current, and could be used for ignition purposes without any battery; in practice, however, it would be a very unmechanical arrangement, and it would be practically impossible to move the magnet fast enough to produce the desired result.

In practice, therefore, the difficulty has been surmounted by modifying the shape of the magnet and coil, and rotating the latter. The result is the magneto of the present day, and, though its details vary considerably, exactly the same principles are involved in every case. Before proceeding to details of construction, a short explanation of the laws governing the generation of current may be explained. While dealing with coils, it was mentioned that a current passing through the winding magnetised the iron core; a more scientific way of putting it would have been to say that magnetic lines of force are induced by a current passing through a coil and that these lines all run perpendicular to the planes of several loops of the coil.

Now beginners are apt to get confused at this point, and to imagine that the converse of this law is also true; that if a permanent magnet is placed inside a coil, a current will continue to flow in that coil so long as the magnet remains inside. This is *not* true, but it is true that a momentary current will be induced in the coil when the magnet is first put in position, and another current will be induced (in the opposite direction through the winding) when the magnet is withdrawn, while if the magnet be reciprocated as described above, a rapidly alternating current will be produced. This current is produced not by the presence of the steel of which the magnet is composed, but by the magnetic lines of force which permeate it, and it is the *rate of change of the number of lines passing through the coil* that determines the strength of the induced current, hence the necessity for moving the magnet rapidly.

Now consider a uniform magnetic field with all its lines of force running parallel to each other, and imagine a coil placed *across* this field with its axis (*of winding*) parallel to the lines, when a maximum number of lines will pass through it. Now, if the coil be suddenly rotated through 90 degrees, it is evident that no lines now pass through it, but a current must have been generated in the coil while it was being moved, owing to the change in the number of lines cut. A further turn of 90 degrees will

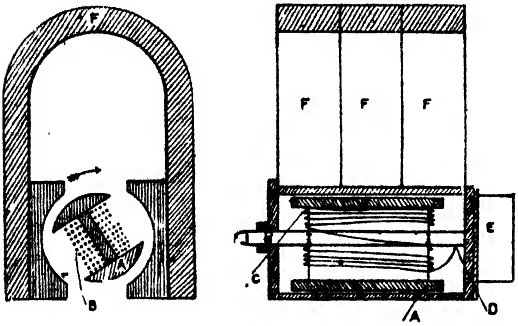


Fig. 26.

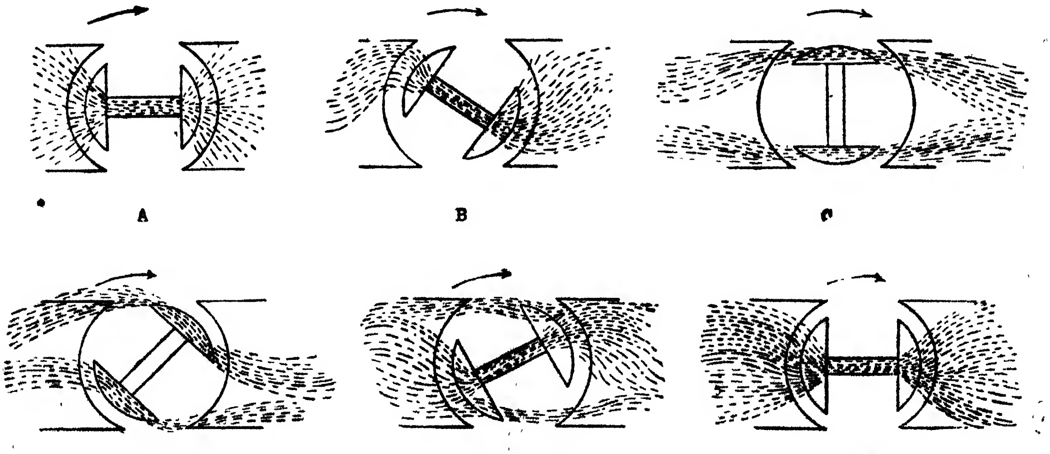
again bring the number of lines passing through the coil to a maximum, and another current will be induced (in the reverse direction); the same cycle will occur during the next half-revolution, making up one complete turn, with one *complete* alternation of current, and, by suitably breaking the circuit, providing four sparks.

In magnetos the magnet is bent to the horseshoe form, and is provided with iron pole pieces bored out to form what is known as an armature tunnel (several magnets are mounted together to form a long tunnel).

What was the primary winding of the induction coil now becomes the "armature" winding, carried out round the channels of an iron core, usually of H section, built up of laminations for the same reason that the core of a coil is made of iron wires, the whole forming the "armature" and being provided with spindles and bearings to enable it to be rotated between the magnet pole pieces. The arrangement is shown diagrammatically in the accompanying illustration (Fig. 26), and, for clearness, this has been kept as simple as possible.

A is the armature core and B its winding, one end of which is earthed by connection to the core (at the point C), while the other end (D) of the winding passes through the shaft to the wipe contact gear (E), which will be dealt with later.

The permanent magnet (F) is shown built up in three parts with brass, or other diamagnetic metal plates at the ends to carry the armature bearings, etc. In the side elevation the shape of the armature is indicated, also the winding, and it is shown in a vertical position, but in the end elevation, with the wipe contact box removed, it is shown in the position when the maximum current is being generated. A similar maximum occurs when the armature has made a half-turn and there are only two maximum current positions per revolution. After what has been said about obtaining four sparks per revolution, this may appear contradictory, but the difference is due to the disturbing effect on the magnetic field of the H section armature. The matter is best explained by diagrams. In Fig. 27, A shows the armature with all lines of force passing through the coil; in B all lines are still passing through, but almost immediately afterwards they, so to speak, snap back, and just before the armature comes to the position shown in C they suddenly take the path therein indicated.



A B C

D. E. F.

Fig. 27.

N

This sudden change in the number of lines passing through the coil has already been shown to produce a heavy current, and the reason for the position just between B and C being the one at which the most powerful current is flowing; hereafter this will be called *maximum* position. Now, coming to D, all lines are still passing outside the winding, but they gradually leak into it again as in E, and, finally, all do so when the position in F is reached. Thus the return of the lines through the winding is gradual, and there is only a weak current generated in consequence. During the next half-revolution the same cycle is, of course, repeated, and it will be seen that there are therefore only two sparks obtained per revolution.

Returning now to the wipe contact (it is in many makes supplanted by a make-and-break), the arrangement is shown in section in Fig. 28. A contact arm (A) is keyed to an insulating bush (B), which in turn is keyed to the armature spindle and rotates with it. The arm (A) is electrically connected to the end of the armature winding either by a slip ring or by taking the end of the wire through a passage, of course insulated, in the armature spindle.

The other part (C) of the wipe contact is earthed by being mounted on the brass plate on the end of the magnet, and is arranged as indicated to give a certain range of advance and retard; there is an internal insulating bush (D), the contact segments coming through it as indicated. These are so set that the arm (A) first makes contact and so completes the armature circuit *before* the armature reaches the maximum position and breaks contact again just when the maximum position is reached. A very heavy current is thus interrupted, and, as has been seen in dealing with induction coils, it is only necessary to have a secondary winding to obtain a high-tension spark.

At this point high-tension magnetos must be divided into two distinct classes; those in which the secondary coil is wound on the armature with the primary, and those in which the armature winding simply supplies current to a separate induction coil, either with or without a trembler attachment; the interruption of the current being carried out as already described. Magnetos of the former class may be called the rotary converter type; they have the advantage of great compactness, though in the earlier productions a great deal of trouble was experienced in getting sufficient insulation; it being no uncommon thing for the high-tension winding to spark across to the pole pieces of the magneto. Modern magnetos of this type are, however, much better made, and such a breakdown is extremely rare, though the possibility is always there, and the danger increases if the armature should get very damp. The danger of dampness, however, has recently been completely eliminated through the introduction by the Bosch Magneto Co. of a magneto completely enclosed in a water-tight metal case. The separate coil system of magneto is best described as the step-up transformer type, and has the merit that perfect insulation can easily be obtained, and also that the coil can be entirely enclosed so as to be free from the effects of salt air far more easily than can the rotary converter type. In the early days, however, the transformer type was seriously handicapped by the fact that the coil was entirely separate from the magneto, and took up a lot of extra room, but the latest patterns are very neatly arranged with the coil placed be-

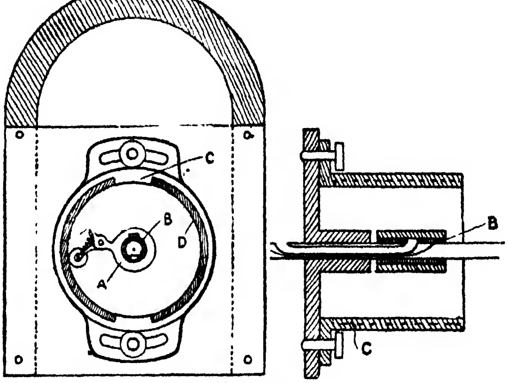


Fig. 28.

tween the two arms of the magnets and just over the armature; the complication of a second primary winding still exists, and it must remain a question of individual taste whether this or the extremely improbable chance of the insulation breaking down on the rotary converter type is most to be dreaded. As a matter of fact, both types have been brought to such a high pitch of perfection, that there is little to choose between them.

The Rotary Converter Magneto.

Of magnetos carrying the secondary coil on the armature there are again sub-divisions; the rotating armature class, and those in which the armature is held stationary, and a rotating (or in some cases oscillating) shield is interposed between the armature and the magnet poles.

There are many different makes of the first class, differing in such details as the construction of the wipe or make-and-break, etc., but the following general principles are applicable to all. The low-tension winding has already been described, but no mention was made of the condenser; its action is precisely similar to that described for induction coils, and it is connected in the same way, across the make-and-break of the low-tension circuit. One set of tinfoil leaves are, therefore, earthed by connection to the magneto frame, the other set being connected to the contact screw or rotating arm of the low-tension gear according to the type fitted.

The inner end of the secondary winding is earthed by connection to the primary winding,

the other end going to the distributing arm of the high-tension distributor, which is, of course, fitted, except in the case of a single-cylinder engine, when the high-tension terminal can be simply connected to a slip ring, whence a high-tension lead is taken to the sparking plug. It has been shown that with a rotating armature magneto there are two sparks per revolution, and to make use of both of these with a single-cylinder engine it would be necessary to rotate the magneto at only one quarter the speed of the crankshaft, which would be much too slow for starting up, and would only give a feeble spark at full speed.

In this case the usual practice is to run the magneto at the same speed as the camshaft, but to have only one contact per revolution in the low-tension circuit, the primary being simply left on open circuit at the other maximum position, so that no secondary spark is produced. For a two-cylinder motor with cranks opposed, the magneto must be run at the same speed as the crankshaft in order to obtain two sparks within half a revolution of each other; the next two sparks have obviously to be wasted, which can be done either by the use of a high-tension distributor with four terminals, two of which are earthed through short spark gaps, or by gearing down the low-tension contact maker off the armature shaft in the ratio of 2 to 1, and putting the contact segments or cams at 90 degrees instead of at opposite ends of a diameter.

For a three-cylinder engine it is necessary to gear up off the camshaft in the ratio of 2 to 3 or to gear down off the crankshaft in the ratio of 3 to 2, the effect of which is, of course, to obtain three sparks from the magneto for every two revolutions of the engine, which is what is required. Now the high-tension distributor has obviously got to have three ways, and must run at half the engine speed; the armature is running at two-thirds engine speed, whence it will be seen that the high-tension distributor must be geared *down* off the armature shaft in the ratio of 2-3rds to 2 equal 4 to 3. A concrete example will make this clearer. Suppose the engine runs at 750r.p.m., the armature must run at $\frac{750 \times 2}{3} = 500$r.p.m., and since the distributor has obviously to run at $\frac{750}{2} =$ 375r.p.m., it follows that it must be geared down off the armature shaft in the ratio of $\frac{500}{375} = \frac{4}{3}$ or 4 to 3.

The case of a four-cylinder engine is very simple; the magneto is driven at the same speed as the crankshaft, giving, therefore, four sparks per two revolutions of the engine, and the rotating arm of the high-tension distributor is simply geared down in the ratio of 2 to 1.

With six cylinders the matter again becomes complicated. Six sparks are required for every two revolutions of the engine, or three sparks per revolution, whence the magneto must be geared *up* off the *crankshaft* in the ratio of 2 to 3, or, if driven off the camshaft, in the ratio of 1 to 3, but in this case the high-tension distributor must be geared down off the magneto shaft in the ratio of 3 to 1. For instance, if again the engine speed be taken as 750r.p.m., the magneto speed will be $\frac{750 \times 3}{2} = 1,125$ r.p.m. The distributor speed will, of course, be $\frac{750}{2} = 375$r.p.m., and it must, therefore, be geared *down* off the armature shaft in the ratio $\frac{1125}{375} = \frac{3}{1}$ or 3 to 1.

Wiring diagrams for various types of engines appear in another section, so it will suffice here to give a simple diagram of the connections of the magneto itself; the one shown (Fig. 29) is for a four-cylinder motor, but with the alterations mentioned above, exactly the same magneto could be used for other numbers of cylinders.

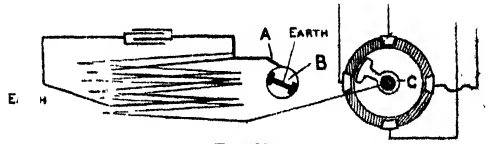


Fig. 29.

The primary coil is shown in heavy lines, and it will be seen that one end is earthed, the other going to the contact blade (A) of the low-tension wipe (B). The secondary coil has one end connected to the primary, the other passing the current to a slip ring (not shown) on the armature shaft, whence it is taken to the rotating arm (C) of the high-tension distributor. This arm is, of course, highly insulated, and the distributor is exactly similar to the type already described. The low-tension wipe and the distributor arm are so set on their respective shafts that both the high and low-tension connections are made simultaneously, as for an ordinary high-tension distributor. The condenser is shown connected across the low-tension make-and-break, as already described.

Advance and retard gear, when fitted, is always arranged to actuate both the high and low-tension circuits simultaneously, since these must necessarily remain synchronised, and in a great many installations the armature shaft is so driven that it is advanced or retarded relatively to the engine at the same time, whereby for any setting, the break in the low-tension circuit always occurs at the moment when the maximum current is flowing. There are several ways of doing this; sometimes the driven pinion on the armature shaft is attached by means of a diagonal slot so that a small fore

and aft movement moves it round through a certain angle on the shaft, or there is occasionally a similar governor-controlled movement of the driving pinion on the engine shaft, in which case the advance and retard is automatic.

In those magnetos where there is no arrangement for keeping the moment of breaking coincident with the "maximum" position, it is usual to set the make-and-break so that contact is broken with the armature in the maximum position with the timing *as late as possible*, to facilitate starting up; when the engine is running fast the extra speed of the magneto compensates for the want of correct setting.

Coupling Up.

In adjusting the drive of a magneto, the engine must be turned till it is just past its dead centre (on its firing stroke in the case of a single-cylinder engine), and then, with the timing lever of the magneto in the most retarded position, the armature must be turned to its maximum position and the chain or gear drive, as the case may be, must be fixed at that point. Usually this may best be done by leaving the pinion loose on the armature shaft while the above adjustments are being made, and then making it fast. One other point must be noted in the two-cylinder opposed crank engine, namely, that with the engine set so that the first cylinder is just firing to be followed half a revolution later by the other, the magneto is set to correspond with the engine (see section on "Wiring Up").

The Simms Magneto (Type S.D.4.

This machine has been chosen as a type of high-tension magneto, as in the first place it is a splendid example of British workmanship, and secondly because it is suitable for four-cylinder engines, of which there are such numbers in these days. The features of the magneto will be readily understood from the diagram (see Fig. 30, which also shows the wiring) in conjunction with the following description. The armature carries the two windings and also the condenser, which latter will be seen at the right-hand end. The armature spindle runs on ball bearings and is driven off the crankshaft, the low-tension circuit being interrupted twice per revolution, while the high-tension distribution arm is geared down 2 to 1 (the gear wheels being omitted in the diagram). One end of the low-tension armature winding is connected to the armature core, while the other end is led through

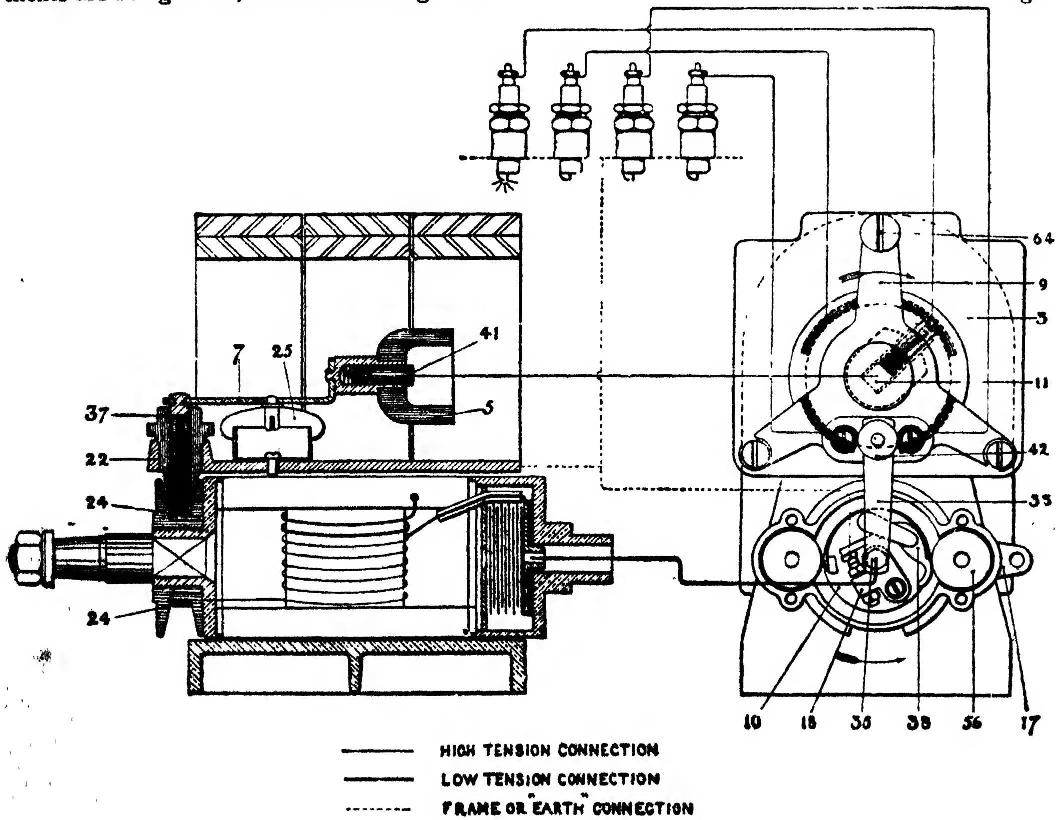


Fig. 30.

the hollow spindle to the contact-breaking device, the fixed portion of which (18) is insulated, and carries a platinum-pointed screw. The bell-crank lever (38) carries the second platinum, and is connected to the frame of the magneto. Both the bell-crank lever and the contact piece (18), together with the contact breaker disc (10), revolve solid with the armature, and as the end of the bell-crank lever comes into contact with the rollers (56) of the timing lever (17), the two platinums break, owing to the bell-crank rocking on its axis. This sudden interruption of the low-tension circuit induces a current of high potential in the high-tension circuit. The brass lid covering the contact breaker is insulated from the frame of the magneto, but is connected by an inside spring with the screw (35), which latter secures the contact breaker. The brass lid is held by a spring (33), at the upper end of which is a thumbscrew for connecting to a switch, by means of which the low-tension circuit can be shorted to stop the engine firing.

The high-tension winding has one end connected to the low-tension winding and so to earth, the other end being connected to the slip-ring (24), from which the current is collected by a carbon, going thence along the conducting bar (7) to the distributor carbon holder (11), which revolves and distributes the current to the four segments (3), and thus to the sparking plugs. Close to the carbon holder (37) will be observed a porcelain dome (25), forming a cover to the safety spark gap chamber, attached to the aluminium lid (22). Inside this dome and connected to the base of the chamber are four points, while four similar ones are inside the porcelain domes. In the event of any interruption in the high-tension circuit, the spark is discharged across the gap, and thus the winding is protected from danger.

To ensure satisfactory working, care must be taken to have a clean contact between the slip ring (24) and the carbon, and also between the carbon (41) inside the dome piece (5) and the end of the distributor carbon (11). The brush in the distributor must also make clean contact with the segments. The two platinum contacts must be scrupulously clean and free from pitting and should be adjusted so as, when breaking contact, to separate by 0.4mm. The parts are very get-at-able in this magneto; on slacking back the screw (64), the star-shaped locking clam (9) can be turned to one side and removed, freeing a vulcanite disc, which, when removed, exposes the high-tension distributor. The carbon holder (11) can then be pulled out, and at the back is a brass stud engaging with the carbon (41). To get at the contact points, the cover may be removed on pressing aside the flat spring (33), and then, on taking off the casting (17), which forms the timing lever, the contacts are exposed.

There are, of course, many other types of rotary converter magneto, some having a stationary armature and rotating field.

The Eisemann Magneto (Type E.K.4).

The Eisemann firm, of Stuttgart, hitherto associated with magnetos of the separate-coil type, have brought out this year a type of the self-contained order, where both primary and secondary windings are wound on the armature, but they still continue to make the separate coil type, as this is preferred by many.

A general view of one of the new types, namely, the E.K.4, suitable for engines up to 30h.p., is shown in Fig. 3, with high-tension distributor cover and low-tension make-and-break cover removed. One of the principal features of this machine is the accessibility of make-and-break distributor parts for examination or cleaning. These parts can be taken down in less than five seconds, and they are so securely fitted that practically no dirt can penetrate.

We will deal structurally with the machine. The magnet elements are composed of three pairs, mounted on and screwed to the pole pieces, which in turn are fixed in position to a brass base-plate. The front cheek (see Fig. 31) is screwed to the pole pieces through the holes (7), and the two-to-one gear wheels run in this cheek, the large bronze wheel (8) being fixed to its spindle by a lock-nut (9), which is prevented from shifting by a grub-screw. The steel pinion (11) is keyed to the armature shaft, and four screws (12) secure the pinion to a steel plate furnished with a central steel bush. It will be seen that this cheek, containing the two-to-one pinions, is fitted at the front end of the magneto behind the distributor and make-and-break plates. At the lower end of the cheek is screwed a part cover (13) for the advance and retard plate

Fig. 31.

proper to work on. Taking now the details of the advance and retard, which consist of the plates (6 and 13) (seen in the Figs. 31 and 33). There are grooves in the plate (6) to take the tongues (12) of the plate (13); the movement of the advance plate (13) being limited to 60 degrees by the projection (15) coming in contact with two small screws in plate (6). A spring is fitted behind this plate, which presses against the

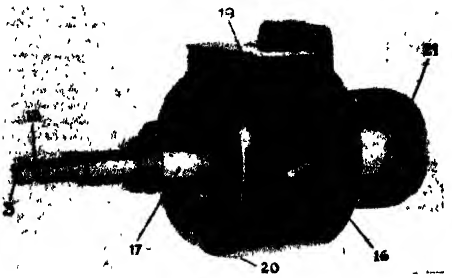


Fig. 32.

projection, with the object of taking up any tendency to slackness in the advance movement.

In Fig. 32 is shown the short shaft and its bearing for carrying the large bronze wheel and the distributing brush. The bearing has two arms (16) which slip over two studs behind the front cheek, being held in place by nuts. The distributor wheel fits on the spindle at 17, and is held by two keys and a lock-nut. On the end of the spindle fits the distributor brush, which is shown in position in Fig. 33; a spring ball inside the brush slipping into the groove (18) to make a good contact, while a key takes the drive—the brush being, of course, bushed. At 19 is a cover for the oil-hole, while there is also a detachable wick holder at 20, by which oil is syphoned to the bearing. The brass cap (21) is merely screwed on to cover the end of the shaft.

The armature is of the usual form, Siemens' H type, giving two sparks per revolution.

Regarding the passage of the primary, it would be as well to make clear first of all the disposition of the make-and-break plate (Fig. 33). The complete plate has a small brass pin behind, which slips into a hole in the advance plate, and is held firmly when the contact-breaker cover, containing also the condenser, is clipped into place by bayonet arms engaging the spring plugs (22). The contact-breaker plate (see Fig. 33) carries the platinum point (23), and the arm (24), which is pivoted and held by the steel bow spring (25), and the flat spring (24).

The transmission of the current from the armature is through an insulated conductor in the spindle to the end of the armature (26). A carbon in the contact-breaker cover presses against 26—this carbon being spring-held and in metallic contact with an insulated ferrotype plate, which forms one side of the condenser. The spring contact (27) presses against this plate and takes the current to the platinum point (23), and thence to earth through the arm (24). It is essential in self-contained magnetos that a good earth return is secured to the earthed end of the primary winding of the armature, and this is provided by placing two sockets containing spring-held carbons in the small two-to-one gear wheel. These carbons run on the face of the front cheek, and so give an effectual return.

Rotating Shield Type

There is a modification of the foregoing rotary converter type in which the armature is stationary, the cutting of the winding by the magnetic lines of force being provided for by a soft iron shield rotating between the armature and the magnet poles. The armature is always fixed vertically in the position shown while the shield rotates. In the position of A no lines of force pass through the coil; but in B, when the shield has moved about 30 or 40 degrees, the lines suddenly take another path as indicated, this time all passing through the armature in preference to passing across the big air gap between the armature and the magnet pole pieces. In C the lines again pass outside the armature winding as shown, and then once more the shield comes to a diagonal position D, and the lines pass through the armature just as in B, while another eighth turn completes the half-revolution and brings the

Fig. 33.

same conditions prevailing in A. There have thus been two sudden changes in the magnetic lines passing through the coils in half a revolution, and there are, of course, four such

periods per revolution, giving four sparks instead of only two as obtained with the rotating armature type. In practice the "maximum" positions of the shield are found to be 30 degrees

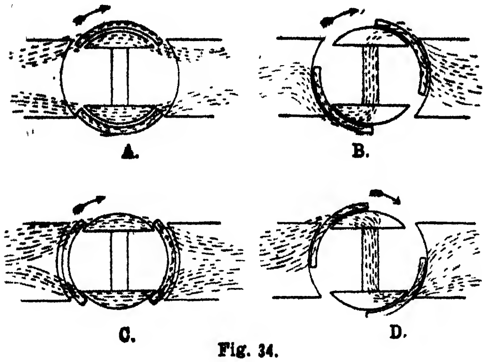


Fig. 34.

past each vertical and horizontal position. This fact renders the magneto peculiarly suitable for multicylinder engines, the arrangement for a four-cylinder motor being very simple. The high-tension distributor is simply mounted on the armature shaft and rotated with it, since the magneto obviously has to be driven at the speed of the camshaft, and this must also be the speed of the distributor. To use such a magneto with a six-cylinder engine it would be necessary to gear down off the crankshaft in the ratio of 3 to 2, or to gear up off the camshaft in the ratio of 2 to 3, and in this case the distributor must be geared down off the rotating shield shaft in the ratio of 4 to 3.

The other most conspicuous advantage of the rotating shield principle is that the armature connections can be made very easily, nor is there the possibility of any of the wires becoming displaced by centrifugal force.

Arc Light Magneto.

Among the best-known magnetos made on the rotating shield principle, and brought out by the inventors of this system, is the arc light pattern, which, as it is probably more widely fitted than any other of its kind, is described here in detail. The insulated end of the primary winding is connected to the brass tube (1) (Fig. 35), mounted on the armature shaft but insulated from it, and, moreover, projecting beyond it. A curved conducting piece (2) fits tightly over the end of the bar, and conducts the current to the piece (3) which carries the platinum contact screw (4). The earthed portion of the low-tension make-and-break consists of the contact lever (5), which is normally kept in contact with the screw by the spring (6). On the end of the rotating shield is a disc (7) having four recessed portions in its face, in which the lower end of the lever (5) can set back, allowing the upper end to make contact with the contact screw. The disc rotates with the shield, and each time the lever comes to the end of a recess its lower end is forced forward, thus breaking the primary contact, the disc being, of course, so set, relatively to the rotating sleeve, that these breaks occur at the "maximum" positions.

On the top of the pole pieces is mounted the condenser (20), one terminal being connected to the contact piece (3) and the other to the body of the machine. This completes the primary circuit. The free end of the high-tension winding is connected to a small and very highly-insulated plug contact piece (8) in the axis of the hollow armature spindle. A small plug on the end of the carbon holder (9) conducts the current to the carbon brush (10), which passes it to the slip ring (11) of the high-tension distributing disc (12). A segment (13) on this disc passes under the four carbon collectors carried in holders (14), whence the current is taken by small conducting pieces to the plug terminals for connection to the motor.

The high-tension distributor disc of course rotates with the armature shield, and the carbon collectors, together with the low-tension contact lever (5), are mounted on a rocker actuated by the lever (19), which gives an ample range of advance and retard.

In this and other magnetos the points to look to are the low-tension wipe contacts, the cleanliness of the high-tension distributor, and the condition of the bearings, which should always be kept well oiled. When oiling up great care must be taken not to allow any oil to get on the armature insulation, which may be very quickly destroyed by contact with lubricants.

Oscillating Shield Type.

There is one other type of magneto belonging to the rotary converter class which deserves notice, the oscillating shield type. The construction of this is the same as the preceding, except that the shield, instead of being rotated, is given an oscillating motion by an eccentric on the

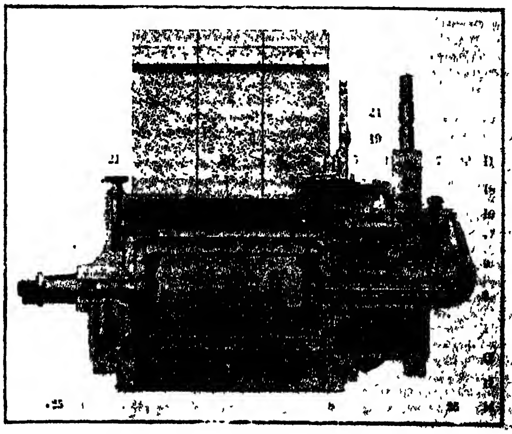


Fig 35.

engine shaft. The chief use of these magnetos is for single or two-cylinder engines; in the former case they can be driven off the camshaft, simply giving one spark per two revolutions, or for a two-cylinder motor (cranks side by side) off the crankshaft.

In all the foregoing types it is very important that the magneto should not be left with its high-tension winding on open circuit or a breakdown in insulation is sure to occur sooner or later. As a safeguard, a safety spark gap is very often fitted, consisting simply of a gap between any convenient point in the high-tension lead and "earth," which is too long to allow a spark to pass under normal working conditions, but which is just short enough for a spark to jump across when any extra high voltage is generated, as when the plugs are not connected up to the magneto, thus leaving the secondary on open circuit. Even with a safety spark gap there is always a heavy extra strain put upon the insulation, and the only safe way of dealing with the matter is to short circuit the primary coil, so that when the ordinary make-and-break comes into action it does not really interrupt the current at all, thus, there being no sudden fluctuations in the primary current, no current is generated in the secondary.

The Step-up Transformer Magneto.

As already explained, this type of magneto has a separate induction coil supplied with current from the low-tension winding of the armature, and possesses the advantage that perfect insulation of the high-tension winding can be ensured, while, in the newer makes, the coil is mounted between the arms of the magnet just above the armature and takes up practically no extra space.

All magnetos of this class are comparatively uniform in the principal features of design, giving two sparks per revolution and being made with the ordinary rotating armature, though, of course, such details as the design of the make-and-break or wipe contact vary considerably, as also does the advance and retard system, etc. The same remarks as to the gearing up of the high-tension distributor, and of the armature spindle itself, apply to the transformer type just as much as to the rotary converter system, so that there is no need to repeat them here.

The diagram shown (Fig. 36) makes the connections of the transformer type perfectly plain. A is the armature winding, and it is simply connected end to end to the low-tension winding of an induction coil, while the make-and-break (C) of the magneto is connected in parallel with the two windings as shown, and it is of a type in which the connection is always made, being only broken just at the "maximum" periods of the magneto. From this it will be seen that the coils are short circuited, and practically all the current generated in the armature winding takes the path through the make-and-break. Directly, however, the circuit is broken at this point the current suddenly is forced to change its path, and to rush through the primary of the induction coil, whereby a spark is produced in the secondary winding, with the small difference, however, from the standard induction coil practice that the spark is produced when the current suddenly passes *through* the coil, not when it is cut off. In practice one end of each of the primary coils and of the secondary are "earthed," as also is the cam disc of the make-and-break.

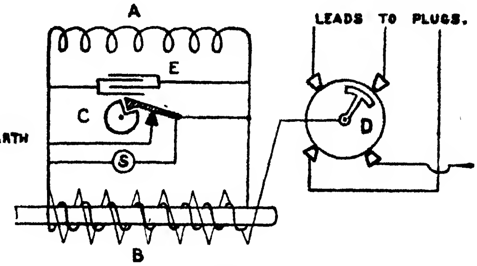


Fig. 36.

The high-tension lead of the coil is connected to the distributor arm of an ordinary high-tension distributor (D) driven, as already mentioned, off the magneto shaft. As in all other cases, a condenser (E) is connected across the make-and-break. The treatment of a magneto of this type is practically the same as for the rotary converter class, and the same care must be taken not to leave the armature on open circuit, or very bad sparking at the low-tension contacts will result; if the magneto is to be kept running, but not used for ignition purposes, the armature winding must be short circuited, which may be done by connecting the blade of the make-and-break to earth through a switch (S), which is left open under normal conditions.

To give a more practical idea of the connections, a semi-diagrammatical sketch is given (Fig. 38). One end of the armature winding is earthed by connection to the armature core at E, the other end, shown dotted at A, passes through the spindle (or a slip ring may be used) to the contact piece (B) projecting through the end of the shaft, whence a spring, shown dotted, conducts the current to the insulated arm (D) of the make-and-break. This arm is supported by an insulating bush on the armature spindle, and also by the insulating pin E projecting from the end plate of the magneto. The rocker arm is pivoted about the point G, also fitted with an insulating bush; the arm carries a roller at one end and a platinum contact at the other connecting D to earth through F and the cam disc H, which latter is keyed to the armature shaft. The direction of rotation of the disc is indicated by the arrow, and it will be noted that it is shaped to give a very sudden lift to the roller on F, thus giving a quick

break. Except when the cam lifts the roller, the armature is evidently short circuited through the make-and-break.

A brass plate (K) is shown in section just above the armature carrying the induction coil and forming an earth connection for its primary and secondary windings. The other end of the primary is connected to the insulated terminal of the condenser (not shown), the other terminal of which is, of course, earthed, and thence the winding is connected to the terminal of the insulated contact arm (D), whence it is obvious that when H disconnects D from earth by breaking contact with the lever (F), the armature current passes through the primary of the induction coil completing the circuit to earth through the plate (K).

The high-tension current generated in the secondary is passed to the rotating arm of the high-tension distributor by means of a brush, usually made of carbon. The high-tension distributor shown (Fig. 38) is for a four-cylinder engine, and is therefore geared down off the armature shaft in the ratio of 2 to 1.

This completes the description of high-tension magnetos.

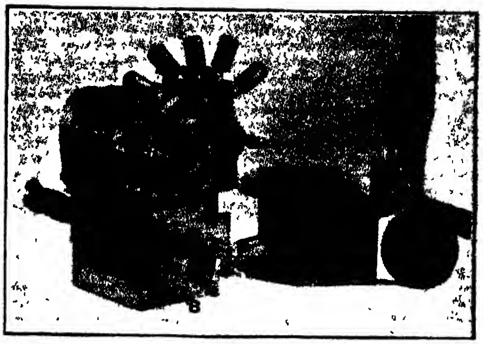


Fig. 37.—A. H.T. distributing arm: B. L.T. make-and-break. In the centre is a separate coil with condenser connections at the bottom, and on the right is a short circuiting switch.

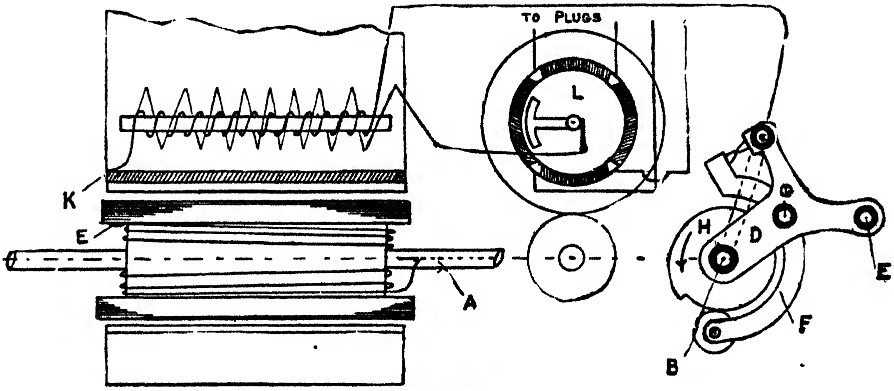


Fig. 38.

Low-tension Mechanical Ignition.

Battery and Solenoid.

This form of ignition was introduced into this country some ten years ago with the American two-stroke engine. It was a system that evoked a considerable amount of interest among engineers, and it gained a vast amount of criticism, the great bugbear in the opinion of those interested being the difficulty it was assumed would be found in keeping a rotary oscillating arm passing into the combustion chamber free and gas-tight.

The first example of this ignition will serve to show very clearly the general principles employed, being a simple and easily understood design.

First there is an oscillatory rotary arm that is actuated from the outside of the cylinder, and carries on the inside a crank or lug that is normally separated from, but which can be brought in contact with, an insulated electrode or pin. The actuating mechanism outside is arranged so that after bringing the oscillating arm in contact with the insulated electrode it will then separate them suddenly.

The electrical circuit consists of a battery to give from 8 to 16 volts in simple circuit with a self-induction or impedance coil, and the insulated electrode, the circuit being completed from the electrode to the movable arm, and thus through the frame of the machine and a switch to the other pole of the battery.

The action is as follows: the mechanical movement brings the rocker arm in contact with the insulated electrode, and the circuit being completed the current flows through the impedance coil, which usually consists of about

3lb. of No. 16 copper wire wound on about 1lb. of soft iron which should be laminated, magnetising the iron, which process of magnetism impedes or checks the flow of current until the iron is fully magnetised. On further movement of the actuating mechanism the circuit is broken by the movable arm being struck away, and now the energy stored in the magnetised iron is given back to the system in the form of an induced current, the electro motive force of which may be anything from 50 to 200 volts, and a momentary arc is struck between the separated points, thus producing an intense spark of great volume.

The advantages of this system are low maximum electro motive power, for it must be remembered that the voltage of a high-tension system reaches a good many thousand volts, and consequently is much more liable to short circuit and leak.

There are no delicate contacts to keep in order, the only contact, the one inside the cylinder, being automatically kept clean by the fusing of the metal surfaces due to arcing.

The insulation of the insulated electrode is not nearly so important as that of the high-tension plug.

The disadvantages may be summed up in the word "mechanics," and they have been almost without exception mechanical weaknesses in the actuating mechanism. In dealing with the difficulty we will refer to the sketch (Fig. 39) of the movable electrode, and it will be seen that the problem is to pack a moving spindle (A) entering a combustion chamber (C) in such a manner that it will be perfectly free to revolve and yet be gas-tight. In this instance the packing consists in turning a shoulder (S) on the electrode (A), which being pressed against the face of the sleeve (B) forms a gas-tight joint. It will be readily understood that this sleeve and spindle would get very hot, and would tend to gum up the lubricating oil that finds its way inside and cause the spindle to bind. This is obviated by passing the sleeve through the water-jacket (D) in the manner shown, and we may mention that many years' experience with an ignition of this type has proved that this runs as perfectly as any other ordinary piece of mechanism.

It will be noticed that the sleeve passes through the water-jacket (D), and fits into the cylinder wall, which is provided with a taper hole to receive it, and this construction allows the sleeve to be ground into this hole without any chance of leakage into the water-jacket. It is held in position by a screwed sleeve (E) and the lock-nut (F). It will be noticed that there is a considerable amount of play left between the hammer piece and the end of the sleeve. This is to allow any rust that may have collected between the two electrodes to be worked off by moving the spindle backwards and forwards in the sleeve. The electrical connections are clearly shown in this diagram.

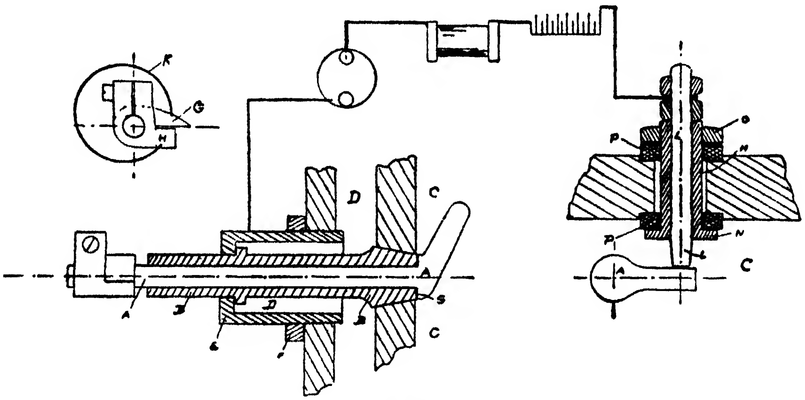


Fig. 39.

With regard to the actuation of the movable electrode, this may be carried out in many ways, though in this case the electrode is fitted with a hammer and anvil piece (H). The anvil piece is secured to the spindle, and the trigger is free to revolve on the same, but the two are held in contact by means of a circular clip spring (K).

An eccentric (F) (Fig. 40) mounted on the shaft has its rod (R) carried in a swivel guide (G), so that the further end of the eccentric rod or tappet piece (T) moves in an elliptical path. On the up-stroke it moves towards the hammer, which it engages and forces upwards, rotating the spindle, anvil piece, and internal contact piece until the latter engages with the insulated electrode. This arrests the motion of everything but the hammer, which continues to rotate, expanding the clip spring (K) until it disengages from the tappet piece, which at the top of the stroke moves away from it. On disengaging it is brought smartly on to the anvil piece, and by its inertia rotates the spindle and

separates the contacts, there being a stop inside the cylinder (not shown) to regulate the amount of the separation.

It will be noted that the rod is joined to the eccentric by a spring guide (S). This is necessary, as otherwise should the direction of the engine be reversed, the tappet piece falling on the top of the hammer, which is arrested by the internal stop, would cause something to fracture. As it is arranged, the spring (S) is

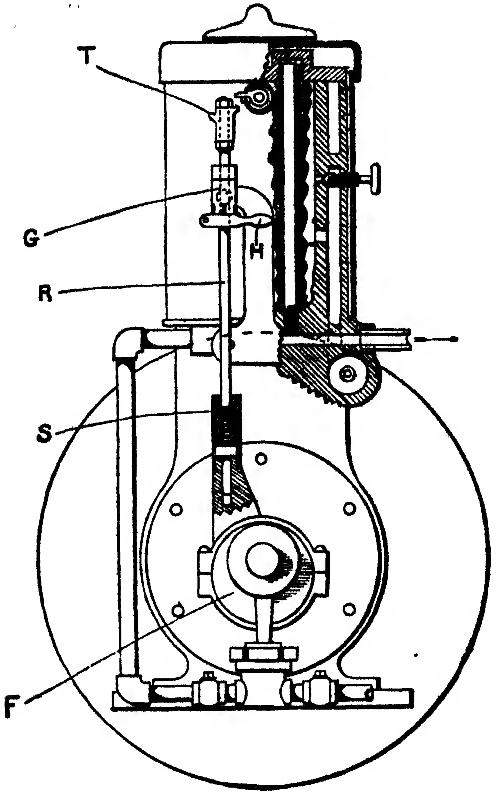


FIG. 40.

compressed and brings the eccentric rod to its normal position when the tappet has swung clear.

The spark is regulated by allowing one or the other of the tappet pieces (T) to engage on the hammer, which tappet pieces are arranged at different heights and can be brought into play by the movement of the handle (H), which by means of a feather and slot in the eccentric rod rotates the latter as desired.

An important point is to insulate the fixed or insulated electrode. A very good way is to slightly counter bore the cylinder cover or part where the electrode passes through, and to make the hole through the same of a greater diameter than the electrode sleeve (M) through which the electrode is screwed. A collar (L) is provided at one end of the sleeve, and at the other is a washer, nut, and lock-nut (O).

Mica washers (P) are provided to fit both sleeve and counter-bore, and the result is that an air-tight joint is made and the sleeve is centred in the hole.

Make-and-break Gear.

One of the essentials of a good gear is that the rapidity with which contact is broken shall be independent of the speed of the engine, otherwise a separate system of ignition for starting up will almost certainly be required. The type illustrated (Fig. 42) is a very serviceable one, and possesses the merit of simplicity. The upper drawing is supposed to be a horizontal section through the side of the cylinder, the water-jacket being, of course, taken round it, and shows the insulated low-tension plug (P), and the rocking lever beside it, of which the part (B) is inside the cylinder and makes contact with the end of the plug (P). The outside arm of the rocking lever is forked, as shown, to take the tappet rod (T) (lower part of illustration, which is an elevation of the arrangement). The tappet rod engages with a cam on the half-time shaft in the ordinary way, and is normally held down by its own spring after the manner of a valve, so that the head (H) presses on the fork of the rocking lever and pulls it down, whereby B is kept out of contact with P.

Now when the tappet rod (T) is raised by its cam, the spring (S) pulls up the forked arm of the rocking lever, the arm (B) of which, inside the cylinder, then makes contact with the plug (P). The back of the cam operating T is cut away very steeply, and so gives a sudden release to the tappet rod which, under the influence of its spring, hits the fork of the rocking lever and so breaks contact inside the cylinder. The whole of this gear is mounted on the plate (C), which is ground to a perfect fit in the cylinder and secured by two studs as indicated.

Timing of the ignition may be varied either by moving the trip gear camshaft relatively to the engine crankshaft, or the ends of the tappets may be moved through a certain range across the axis of this shaft to bring them sooner or later into contact with the cams. To set the timing right relatively to the engine, the advance and retard gear, if fitted, should be set to a midway position, and the camshaft so set that the cams *release* the tappets just when the engine is on the dead centre, and in each case of course, on the firing stroke.

Low-tension Magneto.

The place of the battery and solenoid can be taken by a magneto having only a low-tension winding, and for this system the connections are as in Fig. 41.

The brush (A) collecting current from the slip ring of the magneto is connected to the bus bar (B) alongside the cylinders, and switches (C)

connect the bus bar to each of the sparking plug terminals.

The trip gear must be of such a design that the connection to each plug must only be made

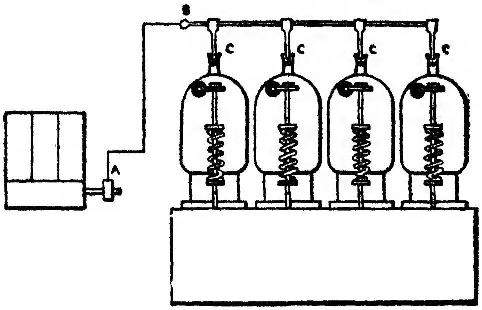


Fig. 41

just before it is to be broken again, for if the plugs were left short circuited, except just at the moment of breaking contact, in a multi-cylinder engine it is evident that no spark would occur at the cylinder supposed to be on its firing stroke, since the current will merely divide itself between the remaining cylinders.

This necessarily rather complicates the design of the trip gear, and, in consequence, at least one firm prefers to use a low-tension distributor, with which, of course, all inoperative plugs can be left short circuited. A diagram of connections in this case appears herewith (Fig. 43).

The trip gear is very roughly indicated, and its exact method of operation is not shown. The magneto is set relatively to the trip gear so that each of the breaks occurs when the armature is in a "maximum" position.

Rotating Shield Type.

The rotating shield principle is, of course, applicable to low-tension magnetos, and still further simplifies their construction in that not even a slip ring is required, the live end of the armature winding being taken straight to a terminal, and thence to the bus bar, or low-tension distributor, as the case may be. A magneto of this type will give four sparks per revolution, and so must be driven at a suitable speed, as already described for high-tension magnetos.

Oscillating shield low-tension magnetos are also to be met with; they require the same treatment so far as arranging the drive is concerned as their high-tension prototypes.

In conclusion, it may be pointed out that connections could be still further simplified by putting all the make-and-breaks in series, leaving all short circuited except at the moment of firing. The only objection to the plan is, that should one contact become sooted up or broken, or should the trip gear of one cylinder get out of order the engine will stop, and on this account the system is never adopted on modern

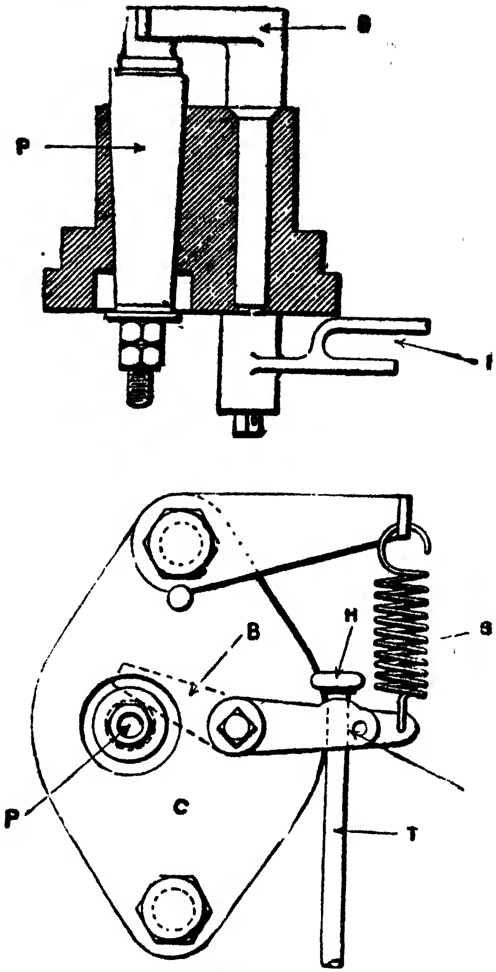


Fig. 42.

engines, though we believe that in some early experiments with low-tension ignition series connections were used, and that endless trouble was experienced in consequence, though of this we cannot speak with certainty.

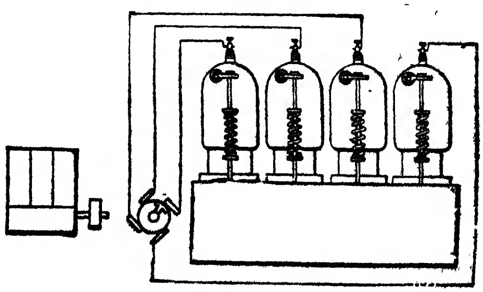


Fig. 43.

Bosch Magnetic Plug Ignition.

The new Bosch magnetic plug ignition consists essentially of a low-tension magneto and patent magnetic plugs (system Honold), which latter take the place of a mechanical make-and-break gear. The great advantage of this form of ignition over the ordinary low-tension is that no extra cam and make-and-break tappets are required, as the interruption is effected by the current itself. There are few wearing parts in the plug, and these can be easily renewed. The fact of all the working parts, other than in the magneto, being in the plug itself enables this system to be adapted to any motor without the necessity of special fittings, while the simplicity of the invention allows of its being easily understood and kept in order by even the inexperienced.

We will now give a description of the magneto (see Fig. 44). Between the pole shoes of the double magnets (1) rotates a shuttle armature (2) carrying two current-producing windings—the main and auxiliary, one being a continuation of the other. The beginning of the main winding is connected to the armature core, and the end connection of both windings leads to the contact piece (3), which passes through the hollow portion of armature spindle, being insulated from the latter. This contact piece carries on the outside the contact breaker disc (6), to which it is electrically connected. The auxiliary winding is connected with the connection piece (23), into the nose of which screws the fastening screw (4). This screw fixes the contact breaker and at the same time conducts the current to the contact piece (5). The contact pieces (3) and (5), as well as the screw (4), are insulated from the armature and also from the contact breaker disc (6). The contact piece (5) carries a platinum screw (7), which is pressed against the short platinum screw by means of a spring (8) that is fixed to the bell-crank lever (10). The latter is electrically connected to the contact breaker disc, and thus short-circuits the auxiliary winding as long as the two platinum points are in contact. This short circuit is, however, interrupted as soon as the bell-crank lever is depressed by the steel segments of the timing gear.

The connection of the main winding to the distributor is made as follows: A brass cap (12) is fitted tightly over the contact breaker, but insulated from the same. A carbon brush, mounted on a spring, is fixed into this cap and presses against the electrically-connected fastening screw (4), thus completing the circuit through the cap (13) and spring (14) to the centre carbon (16) on the distributor. In the distributor disc (17), carbon brushes are placed round the centre carbon (16), the space between them being equally divided into a number of brushes, according to the number of cylinders on the engine for which the magneto is intended. Each of these brushes is in connection with the terminals (18) on the outside of the distributor disc, which in turn transmits the current through single wire cables to the corresponding magnetic plugs. To accomplish this, gear wheels are provided, the larger one carrying a brass segment (19), which distributes the current from the centre contact brush to the various terminals.

The method of operation is as follows: The current generated in the two armature coils attains a maximum twice per revolution, the short circuit of the auxiliary coil being interrupted at the moment of sparking and the main current reinforced by the extra current is then conducted over the distributor to one of the magnetic plugs, which latter will now be described.

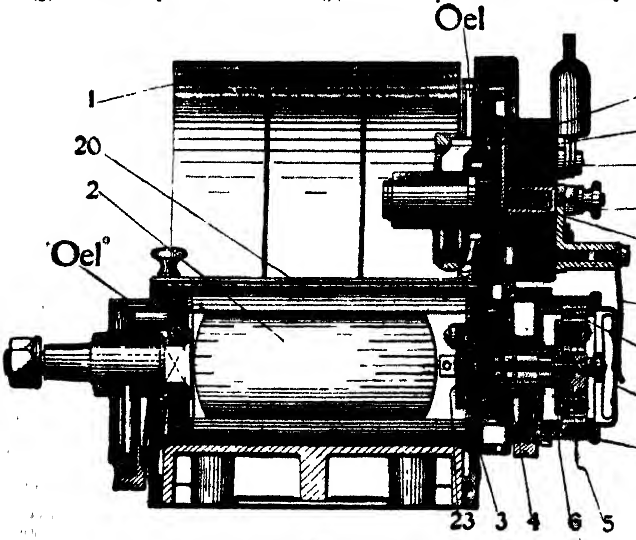


Fig. 44.

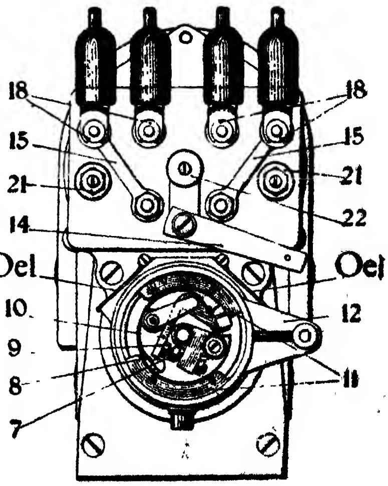


Fig. 45.

The plug consists essentially of a hexagon body (23), above which is the magnetic coil (5) in an iron sleeve (4). The central portion of the plug contains interrupter lever (1), the pole piece (2), and a U-shaped spring (3). The

Fig. 46.

part marked (2) forms the pole piece of the magnet, which, when magnetised, attracts the top part of the interrupter lever, which forms an armature. This lever (1) rests on a steel knife-edge, while the lower end (20) of the lever is kept pressed against the contact piece (21) on the plug body by means of the U-shaped spring (3), which bears on the back of the lever close to the pivot. The spring has the advantage of only having a very small movement, while it is well protected from any hot gases. The two contact pieces just mentioned have a special form, the fixed contact (21) being of V-shape, into which the moving contact (20) drops. The lever also has a slight side play, to enable the contact head when dropping to slide to one side, in case the other is sooted up. Another purpose is also served—a slight rubbing of the contacts is promoted, which tends to keep them clean.

The method of working is as follows: The current from the magnets passes through an insulated conductor to the coil, thence through the connecting screw (26) to the lower magnet yoke piece and the interrupter lever. The plug body is insulated from the remainder of the plug by the steatite cone (22) and the washers (18), and is, of course, earthed. The lever is at once actuated by the passing of the current, the armature being attracted and the contacts separated. We have now the same state of affairs as in the ordinary mechanical make-and-break arrangement, and the interrupted current sparks across the contacts—from the lever to the plug body.

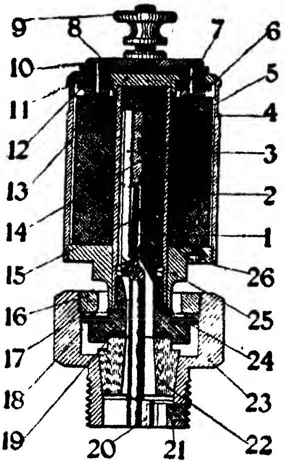


Fig. 47.

1. Interrupter lever.
2. Pole piece.
3. U-shaped spri' g.
4. Iron sleeve.
5. Magnetic coil.
6. Current conducting ring.
7. Current conducting rivet.
8. Mica washer.
9. Nut for terminal.
10. Current carrying plate.
11. Insulating bush.
12. Mica ring.
13. Upper magnet yoke piece.
14. Detachable brass piece.
15. Separating brass piece.
16. Internal ring nut.
17. Centre ring.
18. Mica plates.
19. Packing washer.
20. Contact piece on interrupter.
21. Contact piece on plug body.
22. Steatite cone.
23. Hexagon body.
24. Packing ring for coil.
25. Lower magnet yoke piece.
26. Connection screw for winding.

POINTS TO REMEMBER.

Accumulators.

Never leave an accumulator for more than three weeks without charging, even if not used.

Always keep terminals well greased, but clean the faces where low-tension wires come in contact.

Do not allow dirt or damp to accumulate on the top of the cells.

Have the cells properly enclosed in a box.

Switches.

Never fix a switch in a position where its handle can catch in clothing.

Always arrange a tumbler switch to be "on" when the handle is pressed downwards; this is the standard arrangement in electric light installations, and should be adhered to to avoid confusion.

Coils.

Never mount a coil in close proximity to an exhaust pipe, excessive heat may melt the insulation.

Never put it in a position where petrol vapour can accumulate, as the spark at the trembler is quite sufficient to cause an explosion.

Trembler adjustment sometimes entails something more than setting of the contact screw. If a satisfactory result cannot be obtained by this means, the distance of the armature from the core of the coil may have got too great by reason of the stop screw getting worn, and the armature may be set closer by screwing this down a little.

Provision should always be made for protection from damp.

To reduce the length of the high-tension leads the coil should be got as close to the engine as is compatible with the points already mentioned.

High and Low-tension Distributors.

All kinds of moving contacts should be kept scrupulously clean, and low-tension wipe contacts may be occasionally oiled, but only thin oil should be used.

Fine particles of metal sometimes get worn off by the high-tension distributing arm as it rotates past the high-tension terminals, and these particles, if allowed to accumulate, may cause short circuiting and sparking across from one terminal to another; they should always be carefully wiped away.

Wiring.

Never stint the amount of high-tension wire used for the sake of saving a few pence; allow plenty of slack for the rock of high-tension distributors when the ignition is advanced or retarded.

Avoid long lengths of exposed high-tension wires, and where wires have to be exposed, never tie two or more together, keep them separate as far as possible.

Whenever possible carry all wires through vulcanised fibre tubes, so arranged that water cannot possibly collect inside.

Mark every wire 1, 2, 3, 4, etc., according to which cylinder it has to be connected to, and make sure that each wire can be taken clear of the engine without disturbing its neighbours.

Make it a rule never to simply twist up the end of a wire to make a connection, it is sure to break sooner or later, and will probably do so just when it is not wanted to. Fit proper terminals to each end of each wire; there are a great number on the market to choose from, and they cost hardly anything.

Magnetos.

If one cylinder only of an engine fitted with magneto ignition is misfiring, the trouble must lie in the high-tension circuit, either the plug may be dirty or broken, or that terminal of the high-tension distributor connected to the faulty cylinder may be short circuited. If the misfiring is common to all the cylinders, it is probably the low-tension contacts that need attention.

Never allow any loose fitting to knock against the magneto; constant tapping of the magnets causes them to lose their magnetism.

A magneto should not be installed close to a carburetter; petrol will have a very injurious effect on the insulation, and there is also danger of a fire being started from sparks at the contacts.

If a chain drive is employed, do not allow the chain to get at all slack or the timing of the magneto may vary appreciably if the engine is not running quite steadily. On the other hand, be careful not to have the chain so tight as to strain the magneto shaft. The shaft is weak, and there is only a very small clearance in the armature tunnel; the least whip in the shaft may bring the armature against the magnet poles and strip off the insulation.

Do not be too anxious to put every little trouble down to the magneto, it is one of the least likely parts of a motor to go wrong if it is given fair treatment.

SCREW PROPELLERS.

This simple explanation of some of the principles involved in the design of Screw Propellers is intended merely as an introduction to the more detailed and technical articles which follow, but to the amateur who does not care to dip too far into a somewhat abstruse subject this introduction will be sufficient to enable him to understand the way in which a propeller works and the essential features of its design.

The importance attaching to every detail in the construction of a screw-propeller cannot be over-estimated. Even in big ships where previous experience has proved invaluable to the propeller designer, knots have been added to their speed by changing propellers. Of late the development of high-speed motors and turbines has introduced an entirely new set of conditions, and the results with different designs of blades have been even more widely divergent. Comparatively little is known about propellers. A considerable acquisition of knowledge might almost revolutionise marine propulsion, and the subject is one that cannot be too closely studied.

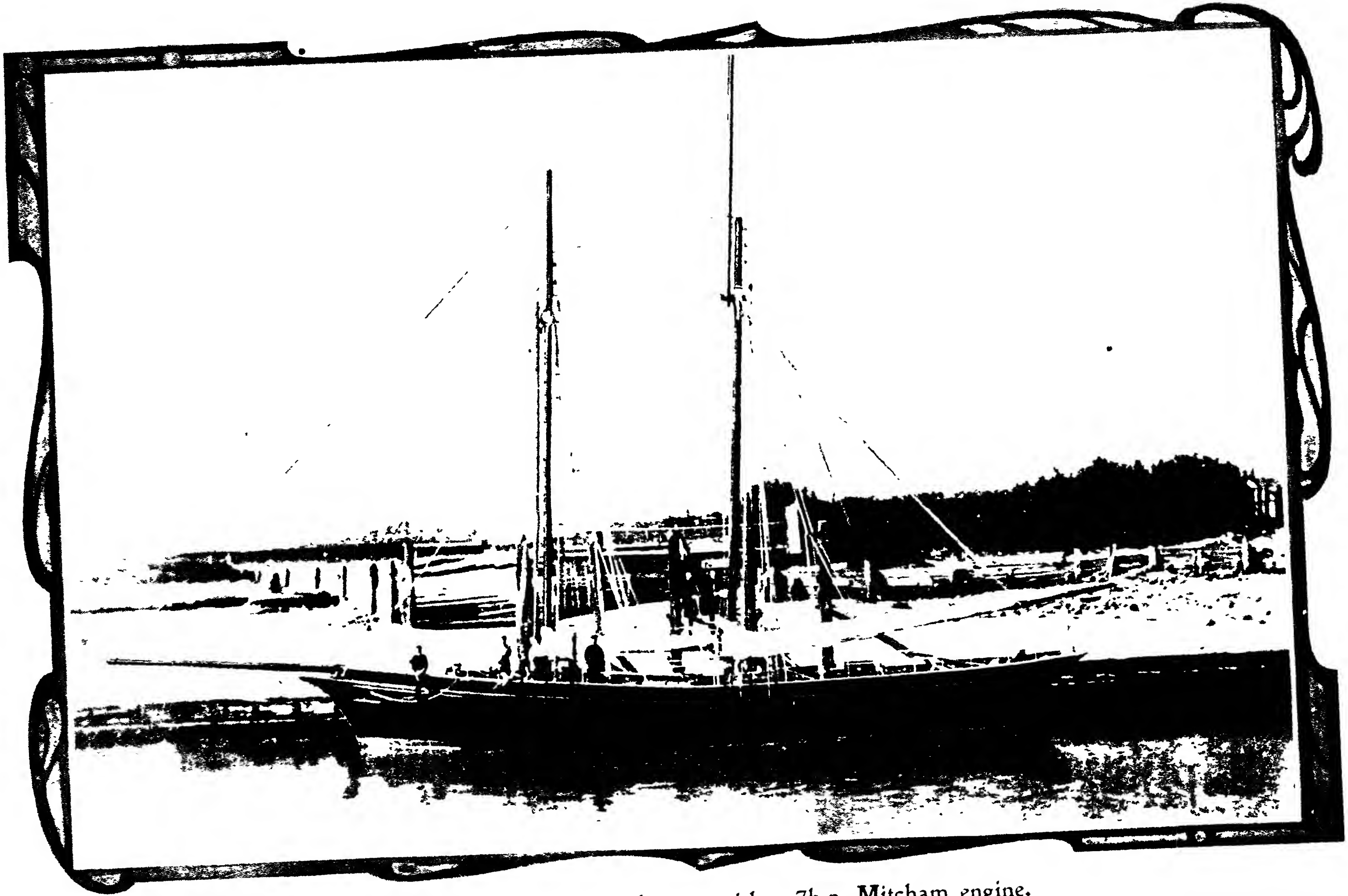
To clearly explain the principles underlying modern screw construction, it is necessary to recall the efforts of the pioneers in this work. After some experiments, beginning with a screw of one complete turn or thread, it was soon discovered that the best results were obtained with a propeller composed of two blades, diametrically opposite, the breadth of each being equal to the one-sixth part of a complete thread. The pitch of these screws was necessarily large, but the thread itself was thin, though deep, consisting, as it did, of a strip of sheet iron wound spirally round a mandrel.

The early screws—using the word in its modern sense as a contraction of screw-propeller—were all two-bladed, but, well as these worked in smooth water, the violent strain to which the blades and shaft, together with the hull, were subjected in a rough sea, when the screw was alternately covered and uncovered by the water, led to the adoption of three- and four-bladed propellers. Three-bladed propellers are not, perhaps, in such general use as the four-bladed on large vessels, because the loss of a blade to the former entails a much greater strain upon the engines than it does with the latter, but on motor launches the three-bladed type is by far the most common.

Thus far the screw had been evolved by practical experiment; no theoretical investigation had as yet aided in its improvement. Soon afterwards, however, when it became apparent that the screw would oust all other methods of propulsion for steamers, the mathematical study of it was commenced. To this day, however, the construction of screws is subject more to the designer's individual ideas and a few accepted empirical formulæ than to any mere theoretical calculation.

Having sketched the considerations which determine the number of blades to be used, we can now proceed to see what further conditions govern the choice and adoption of a certain screw. In one revolution of the screw the vessel should move forward through a distance equal to the pitch, but in reality it does not; it moves through less, owing mainly to the fact that the screw does not obtain a perfect grip of the water. Owing to the inertia of the water, the rotation of the screw creates a pressure on the blades in a direction fore and aft; to make this clearer it may be said that because the water behind the screw does not immediately move, the screw itself must move forward or backward, as the case may be; the action is analogous to the motion of a screw when driven into wood. To this forward pressure on the back of the blades must be added another pressure in the same direction, not differing much in intensity from the former, but acting on the other side of the blades, and due, so to speak, to a sucking effect caused by the displacement of water from that side of the screw. It is owing to this action that the lines of a boat assume such importance, due to the necessity for securing free delivery of water to the propeller. The distance by which the forward motion of the boat, for one revolution of the engine, falls short of the pitch of the screw, is known as the slip; the ratio of the slip to the pitch is usually from 15 to 20 per cent., occasionally rising to as high as 25 per cent. The intended speed of the boat being known, one adds to it the slip for the same unit of time, and dividing by the number of revolutions per minute of the shaft, the required pitch of screw is obtained.

The ratio which the pitch bears to the diameter of the screw is known as the pitch ratio; the diameter of the screw is, of course, measured from the tip of one blade to the tip of the



"Peggotty," an auxiliary schooner with a 7h.p. Mitcham engine.

opposite one. It has been found that in certain cases the ratio may be between .8 and 2.5 without any appreciable variation in efficiency, although the extreme values present other drawbacks; and they correspond to the ratios used in screws which have given most satisfactory results. By mathematical calculation the best theoretical ratio can be obtained for any shape of hull; but, unfortunately, this does not agree with the ratios found by actual practice; this is by no means due to any flaw in the mathematical theory, but to the difficulty of obtaining a true expression for the prevailing conditions.

There remains to be calculated the blade area. A few explanatory remarks are necessary. The tip of the blade, during one revolution, obviously sweeps out a circle, and this is known as the disc circle. The area of any simple portion of a helix, or screw thread, is not easily calculated, much less easily then the area of a screw blade, which generally has a complicated peripheral shape. To overcome this difficulty the area of a screw blade, when projected on the disc circle, is generally used for calculation. It has already been remarked that the earliest investigators adopted a blade area equal to one-third of the disc area: viz., two blades, the area of each of which was equal to the one-sixth part of a complete screw thread. Obviously, then, combined they had an area of one-third of one complete thread, and this ratio remains in the projection on the disc circle, making the blade area equal to one-third of the disc circle area. Compare this with the blade area used in some of the Yarrow destroyers, which is almost exactly .35 disc area, or just over one-third. However, this figure is by no means universally employed; the limits usually are from .3 to .45 disc area depending chiefly upon the lines of the hull. It must by no means be believed that satisfactory results are certain to be obtained in all cases by adopting any value between these limits. Indeed, in many cases a very much larger area has been found desirable, notably in boats with very fast-running engines. "Wolseley-Siddeley," for instance, with engines running at over 1,000r.p.m., required enormous blade area. Again, take the case of the new coastal destroyers whose turbine engines run at 1,150r.p.m. and drive the boats at about 27 knots, the blade area is extremely large. For every new type of hull a series of experiments is necessary to determine the exact blade dimensions, as well as to find the most suitably shaped blade. The blade area is now divided by the number of blades, and the area of each blade is then obtained.

The shape of the blade to be adopted primarily varies with each designer; a common rule is to give the blades an elliptical shape, the breadth of the blade forming the minor axis and the length of the blade from the centre of the shaft to the outer edge being the major axis; this may be varied by cutting off and rounding the outer edge. Again, the ratio of the major axis to the minor may be varied almost indefinitely, each variation giving a different shape. In one particular, however, all designers are agreed—that is, in cutting off the inner part of the blade and making the boss larger than is absolutely necessary for strength; this inner portion of the blade, if left, would only produce a rotation of the water rather than a backward motion. The edges of all blades are bevelled off to cut the water more easily.

The material of which a screw propeller is generally made is either phosphor-bronze, or some other bronze; not that bronzes are stronger or more rigid than steel, but they combine strength with the property of retaining a better polish, and a polished blade surface is of paramount importance. A propeller, after only a comparatively short immersion in water is liable to become coated with weeds or shells, and when this occurs a serious loss of speed is the result.

Friction plays quite a large part in the efficiency of a screw propeller, and it is a consideration of this which governs the whole design of a screw; every detail is influenced by this consideration, which, however, is so essentially a mathematical question as to place the truly correct design of a propeller in the hands of only our best shipbuilders. It is much to be regretted that they are so reticent on this subject; although at the same time it is unlikely that they, as business men, are going to give free publicity to data and experience which have cost them years of time, and, perhaps, thousands of pounds to obtain.

THE PROBLEMS OF SCREW PROPULSION.

A Complex Problem.

Few subjects, if any, have borne a greater wealth of literature than the complex, and often unintelligible, results which surround and follow the operations of a screw propeller. Sometimes a new and different propeller is fixed upon a ship, with the unexpected result that a knot or more may be gained or lost by the change, and, notwithstanding the above-named superabundant literature, plus the "rule of thumb" or acknowledged guess-work, we remain almost as much in the dark as ever concerning what has really happened in consequence of the application of the new form. Of mathematical disquisitions concerning the propeller there are no end, and experiments also lead up to much the same conclusion as the late Mr. Robert Griffiths expressed in his half-joking statement that "a plain, flat sheet of iron, set at about 40 degrees to the plane of rotation, would give, within 5 per cent., as good results as could be got from the most carefully-designed propeller!"

Of course, this epigram is somewhat exaggerated, and Mr. Griffiths, himself a great authority on the subject, knew perfectly well what were the limitations most suitable for range, pitch, and area of the screw blades. This, however, is certain, from experiments tried by pure accident, that a broken propeller often gave better results than the same propeller gave when complete, and that a single blade, with all the others broken off, enabled a boat to do quite a respectable performance. This was shown on a tug-boat, in the presence of Mr. Griffiths and the author, where two blades out of three got broken off, and one blade brought the boat safely home, nobody being aware of the accident until she was placed in dock.

Thus it would appear that very great differences may occur in the area of screw propellers, or in the number of their blades, and very little change take place in their performances. But the item which permits of the least variation is the one which, unfortunately, is varied incessantly, namely, the "pitch" or advance of the screw in any single revolution, as if through a solid medium.

Propulsion through the water, or on its surface, is carried on in a variety of ways, but there is one separate underlying universal principle, namely, that for every movement of the ship forward there is a movement of corresponding value by a column of water backwards. This principle and its bearings are not always realised by amateurs.

Action and Re-action.

As a preliminary to a consideration of the problem of screw propulsion, we may well commence with an examination of the methods by which movements of the inhabitants of the seas swimming on its surface are carried out. Here, again, it is in accordance with one universal law that these movements are controlled, namely, that for every advance forwards there is a corresponding movement of equivalent value in ft. lbs. per min. or horse-power driven backwards. These movements are produced in various ways. In the lower orders of life, the cilia or hairs of minute organisms serve a double purpose. In the rotifera, for example, they are so arranged that when these creatures are anchored to a stone they serve to bring food by creating a current of water, but when the organisms are free to move about, the same hairy appendages act the part of propellers, by corresponding movements which brought them food when they were fixed. It is, however, from the larger inhabitants of the ocean that we learn most as to their means of making progress through the water. The octopus converts itself into a pump, sending a current of water backwards, thereby propelling itself by spasmodic movements forwards. This principle has been used in the construction of vessels such as the "Waterwitch," provided with an internal centrifugal pump. These schemes, however, have not, up to the present time, received any such measure of success as would lead to the impression that the screw propeller might be in any jeopardy owing to the competition of such devices. In connection with this mode of construction it may be noticed that whether they drive a column of water backwards, below or above the surface, corresponding results will follow, thus showing and proving that it is the weight of water thrown back that gives the necessary resistance to ensure progress forward, and not any resistance by water below, acting after the manner of a solid body.

If observations be made on the swimming of a frog or a duck, it may easily be seen that the legs, with their large webbed feet, act almost exactly the part of a paddle-wheel, giving a movement directly backwards, while the creature itself moves forward. In the paddle, however, there is a loss of power from water escaping sideways, which is prevented in the case of a frog or duck by the construction of their feet, and the semi-elastic character of the webs between their toes, giving a "feathering" arrangement of singular perfection and beauty.

Analogy of Fishes.

These, in short, are the chief methods of progression until we come to the action of fishes, which corresponds most closely with that of a screw propeller. The tail of a fish, moving sideways in a sort of wriggling fashion, propels the creature forward in much the same manner as a man in sculling with an oar over the stern of a boat moves it sideways in one direction or another, and so propels the boat along. There admits of little doubt that an investigation concerning the movement of fishes, more particularly such quick travelling specimens as the Spanish mackerel, would gather together an amount of useful information of a most valuable character, such as might go far towards settling some disputes as to actual facts, the uncertainty of which so encumbers the whole subject of screw propulsion. Not that observers of the few experiments hitherto made intentionally misrepresent them, but more generally because in all hydraulic experiments, it is doubtful what any new combination will really do until it has been put to the test. American experiments to ascertain the exact movements of a fish in swimming were made by causing its swimming to occur in shallow water: taking a succession of photographs by a sort of cinematograph, so as to show all the swimming phases of movement from a certain position, until a return to the same position. There does not, however, appear to have been much made of a comparison between such movements and those of a screw propeller, although the subject would without doubt reward any investigator who may master the complex phenomena displayed by the performance of a fish during its progress through the sea.

The designs for all the movements of animals are all adapted to their needs and conditions of life, so the best we can do is to copy as closely as possible the teachings of Nature, only modifying her constructions in consequence of our inability to use the same sensitive material which she supplies in such abundance.

No animals move in exactly the same way as a locomotive engine, yet the principle of converting a strong muscle of short stroke as a lever of the third order is exactly analogous to the use by a locomotive of the same third order of lever, only disguised into the form of a crank and a wheel: so, in the case of screw propellers, we have to follow out the same principles that govern the movement of fishes when we want to ascertain points that may exert much influence in the general construction of a screw propeller.

The Early Theory.

Since the screw was first dreamed of by Hooke, in 1680, noticed by scientific men early in the 18th century, and finally applied and brought into general use in the 19th century, attempts have been made in numerous quarters to devise a satisfactory theory to account for its working. The original theory, in all these attempts, was based upon the false assumption that water acted the part of a solid body, and that the screw wormed its way through this ideal and altogether impossible fluid. This theory lent itself to a very simple rule that the advance of the screw and vessel to which it was attached should, under all circumstances, be equal to its pitch. No doubt this proportion came right in some cases, but in most others the progress was less than the pitch, and this was put down as positive "slip." Matters, however, became very complicated when it was discovered that with a singular perversity some vessels went faster than was due to the pitch, and this was called "negative slip," a confusion of terms which reflected little credit upon those who endeavoured to explain what in itself was a manifest absurdity. "Negative slip" becomes simply a kind of "perpetual motion" under another name, and experience has shown that many of the best performances have been secured by vessels where the "slip" was considerable, and some of the worst of all in cases where there was no slip, or where what there may be is negative!

Admiralty Experiments.

Our Government does not usually emulate the foreigner by spending national money on matters of interest vital to the whole community, but exception must be made to this general rule in the case of the "Active" and "Greyhound" experiments, and also through the very valuable series of experiments of the late Mr. Froude, which have been continued by his son, for which all proper and convenient provision was made by the Admiralty.

The object of these experiments was to ascertain what, if any, was the difference between the pull on a tow-rope towing the "Greyhound" (1,157 tons) by the "Active" (3,078 tons), and driving the "Greyhound" by her own engines. A dynamometer was placed in the tow-rope, and with this arrangement it was found that the haulage obtained by the dynamometer was 10,770lb., while the speed of the screw was 1,245ft. per minute.

But when the "Greyhound" went at the same speed driven by its own engines, the pressure deduced from its indicator diagrams became 20,830lb., instead of 10,770lb.

Thus the horse-power required to drive the ship by its own screw was double as much as was required on a tow-rope from an independent source of power. Attempts were made on more or less unlikely theoretical grounds to excuse this unexpected result, but, as a matter of fact, it is just what might have been anticipated, when it is admitted that the propulsion of a vessel forward is secured at the cost of a backward current absorbing equal horse-power.

So far as Mr. Froude's experiments have gone, much useful information has been secured, and one important conclusion reached by this acute observer has been described by him in the following terms:

"The calculations point to the conclusion that a very much longer pitch than has commonly been adopted is favourable to efficiency; and that, instead of its being correct to regard a large amount of slip as a proof of waste of power, the opposite conclusion is the true one. To assert that a screw works with unusually little slip is to prove that it works with a large waste of power."

Basis of the Theory.

Now, what is the basis of this discredited theory of screw propulsion, reduced from the lofty standard of mathematical symbolism down to the plain language of simple geometry, explaining it by graphic diagrams, which any-

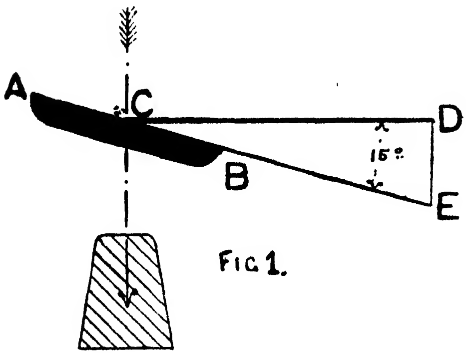


FIG. 1.

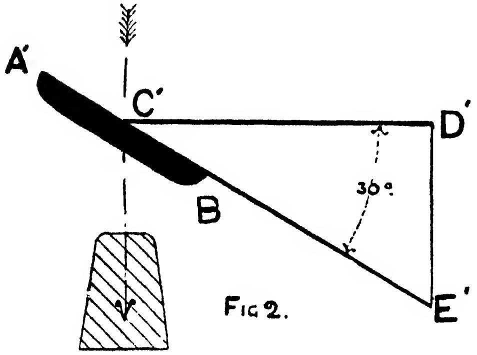


FIG. 2.

one can understand? A screw may be defined as an inclined plane wound round a cylinder. It may be of any desired steepness and any depth of thread, and, when unwound, it is accurately represented by Figs. 1 and 2. In both cases the base is 22ft., which represents the circumference of a screw 7ft. diameter.

In Fig. 1 the pitch DE = 6ft., and the angle of the blade AB, as compared with the circumferential line CD, is DCE = 15 degrees, and with "no slip" this proportion should cause the ship to advance 6ft. per revolution of its screw. Possibly it might travel faster than the current due to pitch in Fig. 1, for this is the kind of propeller where so-called "negative slip" may be found.

Contrasting this now with Fig. 2, where the same base of 22ft. is maintained, the angle $D^1C^1E^1$ alone is altered, being doubled, and now equals 30 degrees. We find the pitch 12ft., which would represent a movement of the ship to that amount, provided there were no slip, or a movement of 6ft. with a slip of 50 per cent. per revolution of the screw.

The original old theory of the screw propeller assumed the blade to slide through the water, a distance BC, thus pushing itself forward, and the ship also, a distance ED, in every revolution made by the screw. But in making any use of this theory it became necessary to make so many allowances that the practical result was hopeless confusion. This theory fulfils none of the elementary uses that every sound theory should possess. It gave no assistance whatever to those practical men who would be only too thankful for any help over so difficult and complex a problem as to the best proportions of a ship and its propeller. It gives him instead a series of empirical rules and doubtful constants, all of which are practically little more than glorified "rules of thumb."

Pitch Angle.

Having proceeded thus far, it would appear that an inclination of the screw blade amounting to about 40 degrees to the plane of rotation should give a propeller possessing a high duty performance, and that any reduction upon this angle is detrimental to the performance of such a screw. This proposition holds good for all diameters, without exception It rules the pitch of a 12ft. screw of a tramp or a torpedo boat with a 3ft. screw, making 600 revolutions per minute. If a screw has to run at a very high speed, it is under present practice the pitch that suffers, and, however good may be the economical performance of the engines and of the boat itself, the sum of efficiency (which should include the propeller) is less than it might easily have been, not by reducing the pitch, but by altering the diameter of the propeller, and so maintaining the best inclination of the screw blade to the plane of rotation. It must be remembered, however, that the figure of 40 degrees is not meant to be exactly copied in every case, for there are certain influences which modify this conclusion, and these depend in a great measure upon the lines of the ship and other matters, which are best considered one at a time, so that at last, perchance, we may discover the complex curves which will produce the best form of screw blades for any ship at its mean speed through the water.

Results of Experiments.

The first and most obviously practical thing to do is to seek and ascertain the results of much experimental research so as to fit a new theory to ascertained facts, and although there have been many thousands of screws constructed, yet the valuable data they might have furnished has never been observed or classified, or, at any

rate, never published. So far as the author is aware, even the direction taken by the currents driven backward by the screw has never been properly ascertained, by public or private investigation, and he can only fall back upon some of his own experiments, taken many years ago, for ascertaining this point. These experiments were made upon a three-bladed Griffiths screw, 3ft. 6in. diameter, belonging to a canal tug-boat.

FIG. 3

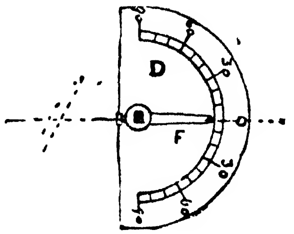


FIG. 4

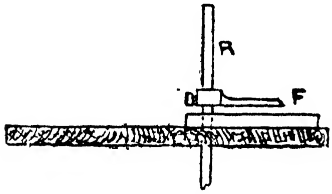
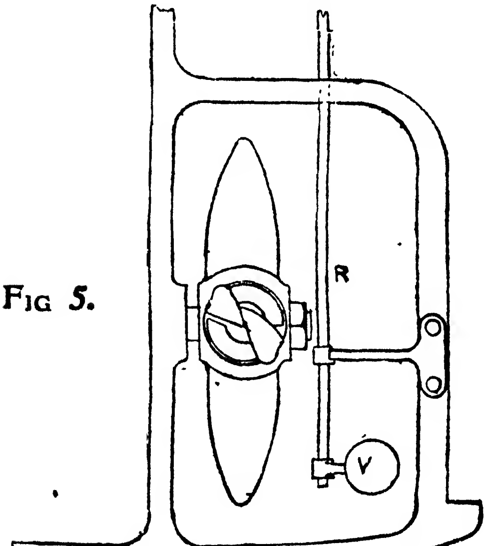


FIG 5.



The apparatus employed is illustrated by Figs. 3, 4, and 5. It consisted of an iron vane (V) attached to a square rod (R), which passes upward above the deck, and is held in position below or above the centre-line of the screw by a bracket attached to the rudder post. At the upper end of the rod (R) there was a finger (F) placed vertically above the vane (V), so that whatever might be the position of the vane, it was exactly known by the finger and dial (D) marked in degrees, and the results of observations on this apparatus revealed some very interesting facts under several different systems of working.

They are all given in the table (on next page), which shows the results of some experiments that were made on a steam tug, with a view to ascertaining the direction of the currents driven backward by the screw. The first column shows the position of the vane at various distances from the centre of the screw shaft. Column 2 gives the angle of the screw blades to the plane of rotation at each distance. Columns 3 to 6 give the deflection angles and the pressures when the screw is propelling the tug alone. The next set of columns from 7 to 10 show the different results obtained when the tug was towing two loaded barges, whilst the last set of columns, from 11 to 14, show how much the deflection angle has increased in every case, and the pressures have considerably altered during the experiments made whilst the tug was moored to a post. The steam pressure and the number of revolutions per minute at which the engine was running in each test are given.

The figures given in the section under the heading "Moored to a Post" would serve to show that the extremity of the screw was only

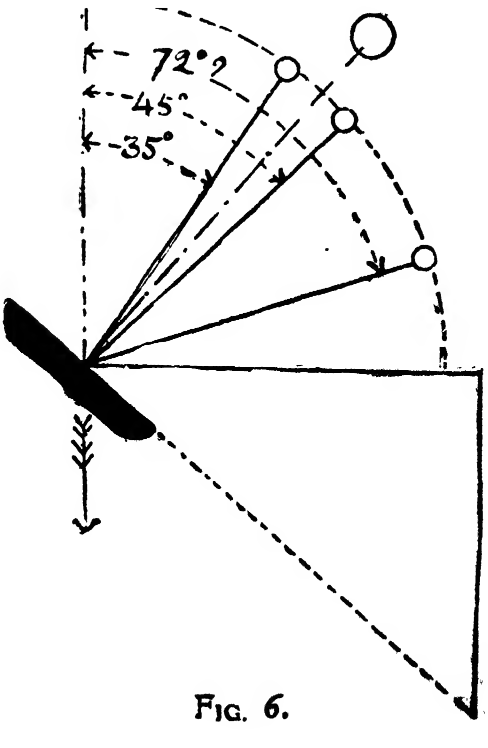


FIG. 6.

Experiments on Steam Tug to ascertain direction of Currents Driven Backward by the Screw in relation to line of Engine Shaft.

Radii below centre of screw shaft.	Angle of Screw Blades to Plane of Rotation.	Propelling itself alone.				Towing two loaded barges.				Moored to a post.			
		Steam.	Revolutions.	Deflection Angle.	Pressure on 10sq. ins.	Steam.	Revolutions.	Deflection Angle.	Pressure on 10sq. ins.	Steam.	Revolutions.	Deflection Angle.	Pressure on 10sq. ins.
Inches	Deg.	lb	Per min.	Deg.	lb	lb	Per min.	Deg	lb	lb	Per min	Deg.	lb
17	41	60	144	35 0	21	60	160	45·0	10	46	136	72·5	4
14	42	,,	—	27 5	18	,,	—	37·5	13	—	—	52·5	8
11	42	,,	—	25 0	15	,,	—	31·0	13	—	—	50·0	13
8	40	,,	—	25 0	12	,,	—	31·0	14	50	144	45·0	11
6	—	—	—	27·5	12	,,	—	31·0	9	—	—	42 5	—
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14

churning the water, while the inner diameter was acting efficiently.

Direction of Water Current.

Figs. 6 and 7 represent the directions of

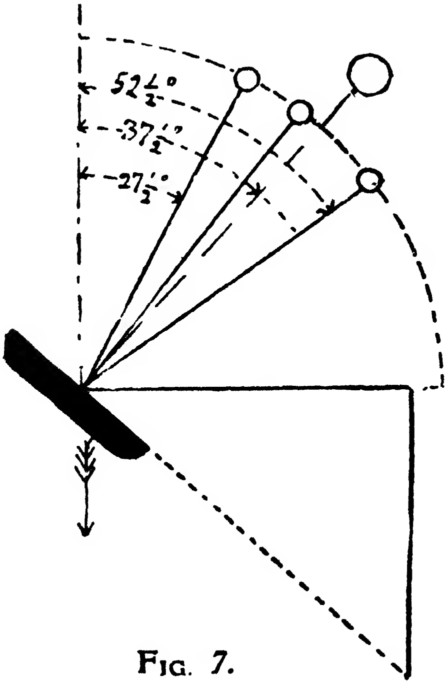


FIG. 7.

the currents diagrammatically, and they point to the irresistible conclusion that the main current driven backward from a propeller leaves the blade at right angles to its surface. It will

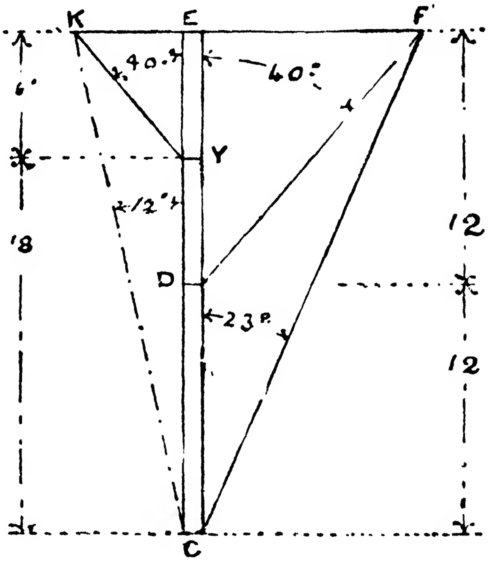


FIG. 8.

be observed that there is here no indication whatever of any sliding action. Indeed, the fact that colonies of mollusca almost seem to prefer the surface of the rotating screw to the rudder or any part of the vessel indicates at once that there can be no sort of scour where such creatures make their nests.

Of course, the statement that the water leaves the surface of a screw propeller at right angles is a generalisation that must be accepted with a certain amount of caution, for there are other causes which modify this action. For example,

where the currents run into the screw from a vessel with a fine run they will differ from the currents entering from a coarse run, and it will be remembered once a current of water is running in a given direction it requires a very considerable side pressure to change that direction.

Besides, the direct action of the screw is modified by the movement of the vessel it is driving. If, in the double diagram, Fig. 8, the ship moves YC, equalling 18ft., forward, while the water current YE, equalling 6ft., moves 6ft. backwards, then the actual direction of the water current is YK for one revolution of the screw. But the ship has moved forward YC, so the relative motion of the current, as observed from the deck, would be CK in the same period of time, and this angle ECK is only 12 degrees instead of 40 degrees, which is the real direction of the current.

Similarly, if the ship be more heavily loaded, a greater current of water, such as DE, is driven back, for a less movement of the ship forward, such as DC. But the actual direction of the water current is DF, while all its useful effect is given out by DE, and the angle ECF, instead of being 40 degrees, is only equalling 23 degrees. Every portion of the screw propeller surface has its own amount of water driven back, and also its own direction of current, so it may well be imagined that, although the sum of these movements may be considered as a single mass of water driven backwards, this does not by any means make the problem more simple.

Loss of Efficiency.

Any diagonal movement of the water current means so much loss of efficiency. For example, in Fig. 8 the line DF represents the direction and magnitude of a current driven backwards 16 feet at an angle of 40 degrees to the line of screw shaft, whilst the ship advances 12 feet. The only profitable driving value, however, is represented by ED, equalling 12 feet. Consequently, the portion represented by EF is altogether lost with the ordinary screw propeller.

Looking at the other side of this diagram we see a current of 6ft., EY, driving the ship 18ft., equalling YC, which is obviously a much more economical arrangement than is shown by the preceding example.

It might be argued that, as currents leave the screw blades at right angles to their surfaces, it should be a positive advantage to employ a screw of low pitch, but such is not found to be the case by experiment, and this is one of those ill-considered arguments where an imperfect appreciation of theory leads to wrong conclusions in spite of the facts.

In such an example of a screw pitch of 15 degrees to the plane of rotation, as shown in Fig. 1, we assume that it belongs to a screw propeller where the ship advances 6ft. per revolution, which equals the pitch, so there is no "slip." It must, however, be admitted that considerably more than 6ft. of water per revolution must be driven backwards. This, for argument's sake, may be considered another 6ft. In such case the total current driven backwards is 12ft. per revolution of the screw. But, as each following blade on its front or leading edge only allows of a movement rated at 6ft. per revolution, the remaining 6ft. dashes itself against the leading edge of each following blade, which, to that extent, serves as a hindrance to the progress of the ship. It is with screws of this character that a positive advantage has often been found by the breaking off of one or more of their blades.

Fine and Coarse Pitch Compared.

This kind of action diminishes with increasing pitch, and at about 40 degrees ceases altogether, and this behaviour of the screw blades in relation to the currents explains why, in the balance of gains and losses, a coarse pitch gives superior results to a fine pitch, for the latter commits a sort of suicide by destroying with one blade part of the work done by the other. The effect of this action can easily be seen in the wake of any screw propeller of short pitch, where the water does not follow in an unbroken column, but separates into a multitude of curls and twists, which would at once condemn the design of a turbine, if such a result were given by that motor. The rules of hydraulics are applicable to the screw propeller and turbine, for these two mechanical arrangements have very much in common. Indeed, the easiest way to examine the blade of a screw propeller, and the action of a jet upon it, will be to assume the blade receiving the effect of a jet upon it, just in the same way as guided jets of water impinge upon the buckets of a turbine.

Action of Jet of Water on Blade.

So that, before entering upon the direct subject of screw propulsion, it will simplify matters to examine the behaviour of a jet of water under conditions which may apply somewhat closely to any single jet which may be found in the wake of a screw propeller. To study the whole mass of jets under their diversified conditions as to direction and velocity would render the subject so hopelessly complicated as to veto all chance of understanding it as a whole. We may look upon one jet as the portion of a current driven backwards, and moving at a given velocity, or as giving a definite pressure. Either method is equally sound, and the conditions are easily interchangeable by the simple formula

$$V = 8\sqrt{H}$$

where V represents terminal velocity, and H the height from which the current comes to acquire this velocity. It will be convenient here to premise that, in order to make the following argument easier to understand, figures may be employed which are not necessarily representative of a good form of screw propeller, nor will it

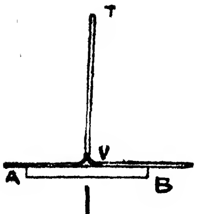


FIG. 9.

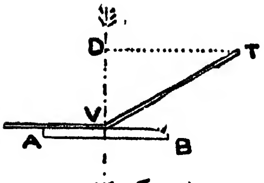


FIG. 10.

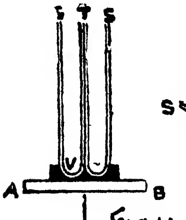


FIG. 11

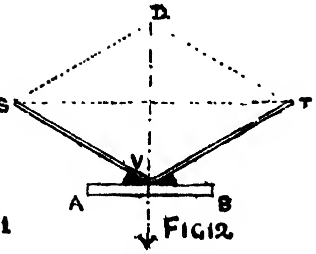


FIG. 12.

be necessary to use fractions, as whole numbers will give quite as accurate results as are required for any present purpose.

It is simplest and most easy to examine the action of the blade of a screw propeller as if it were fixed, and the jet, moving much in the same manner as jets of water act against the buckets of a turbine, with which, as I have said, a screw propeller possesses many points in common.

If, as shown by Fig. 9, a jet of water TV impinges vertically upon a horizontal flat surface AB, it will, on striking, disperse in every direction as from V to A or V to B, and it will give a pressure which may be taken at any convenient scale, as, for example, $\frac{1}{8}$ inch to 10lb. pressure.

If, however, the same jet TV, Fig. 10, be inclined to the surface AB to any angle, say, 30 degrees, it will discharge itself as a film of water towards A, and parallel to the surface AB, and by making VT, equalling 80lb. by scale, and drawing TD parallel to AB, the vertical line DV is obtained, and this measures the direct downward pressure, namely, 40lb., on the surface AB. Both these pressures are due to impact alone, and that of a stream passing away at 90 degrees or less from its original course.

But if, as in Fig. 11, the stream TV fall into a cup AB so deep as to reverse its direction to one upwards, the full velocity of its original impact is used up in raising the jet to the level from which it originally came. In other words, its downward pressure is doubled, and amounts to 160lb. instead of 80lb.

Similarly, if, as in Fig. 12, TV be taken, as in Fig. 10, to represent the pressure (80lb.) of impact, then VS represents the equal force of reaction (also 80lb.), neglecting the losses which always accompany changes in the method of application of any power. After this it becomes only necessary to draw VS, Fig. 12, so that the angle SVA equals the angle TVB, and the length VS equals the length VT. Then draw SD parallel to TV, and TD parallel to SV, which gives the point D on the vertical line, and by thus completing the parallelogram of velocities we find that the downward impact and upward reaction of this stream equals DV, or 80lb., upon the surface of AB. Thus, by comparing Figs. 9 and 11 with Nos. 10 and 12, it becomes clear that, in all cases, the resultant is vertical in relation to the plate AB; and that whenever full power is obtained from a jet of water half comes from impact and half from reaction. This is well-known to designers of turbines of the combined system, but the converse seems hardly so much appreciated by designers of screw propellers.

In this illustration it has been assumed throughout that the jet of water moves and the plate AB remains at rest; but just the same performances can be secured by allowing the plate AB to move backwards, and to absorb half of the power, as in a turbine; or, again, any number or variety of forces can combine to form themselves up as a resultant DV (Fig. 12). Or, again, the whole arrangement may be inverted by moving the plate AB from V to D, and in this modification the streams of water forming a resultant may be anything such as TV due to impact, and SV due to reaction.

Similarly, in the case of a screw propeller, any portion of its blade may be selected and calculations made on this basis. Such calculations are of a somewhat laborious character, yet they afford a very considerable amount of information, and throw new lights upon the whole subject, theoretical and practical, of screw propulsion.

An Example.

It will be remembered that the resultant line DV combines within itself all possible lines of

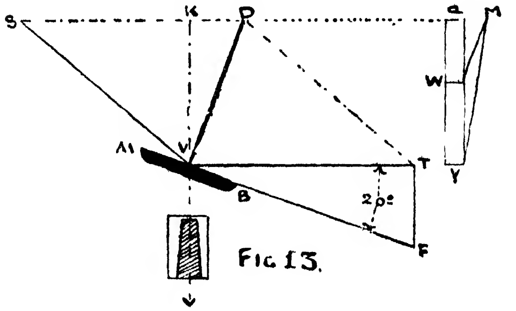


FIG. 13.

force in the stream of water driven backwards by a screw propeller, and a further illustration (Fig. 13) represents the performance of one jet of water removed from its surroundings. The screw blade is marked AB, and its inclination is 20 degrees to the plane of rotation VT. Its pitch TF is 8ft., and DV represents both in direction and magnitude the resultant of the jet

under notice. This jet comprises an impact TV reflected from the surface AB, as a reaction VS, the line of reaction VS being set so that the angle SVA equals TVF equals 20 degrees, and VS equals VT. Completing this parallelogram of velocities by drawing SD parallel to VT, and TD parallel to VS, we arrive at a general resultant DV, which, in direction and magnitude, may be either one item or a general mean of other portions of the current of water selected for investigation and driven back by the action of screw propeller. It includes also the corresponding time movement of the ship per revolution of the screw. If it be assumed that this screw is working without "slip," then WY, equalling 8ft., represents the movement of the ship forward, and Wa, equalling 6ft., the corresponding current of water driven back, while Ya is the sum of both.

As may be seen by reference to Fig. 13, WM represents the amount of current driven back, and also its direction, while MYa is the angle at which it leaves the screw relative to the ship, which angle is nine degrees. The total current passing through the screw is made up by the ship advancing eight feet plus the reverse current Wa, equalling 6ft., or a total of 8 + 6 = 14ft. per revolution of the screw. It has already been mentioned that this arrangement works out badly. We shall show how this important action accounts for a good deal of the mystery surrounding the performance of this class of propeller.

Loss by Following Blade.

For simplicity and easier understanding of this most important subject it has been assumed for Fig. 14 that it deals with a propeller possessing only one blade AB, which is set at 20 degrees to the plane of rotation, travelling from V to T during one revolution of the screw. Thus, TF

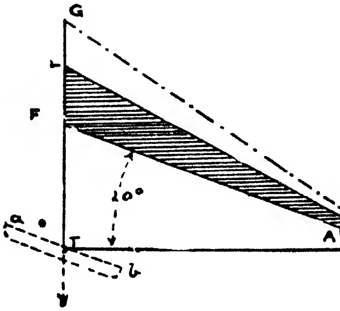


FIG. 14.

will be the pitch, equalling 8ft., and FG the water current driven backward, as in a direct line with TF, and TG will therefore be the total current passing through the screw.

By the time that the leading edge of this blade returns to its original starting place it will find that a current, having an original velocity of 15ft. per revolution of the screw, has had this speed somewhat reduced, say, to TL, owing to the temporary absence of any propelling power, but still there remains a velocity FL in excess of the pitch. Assuming the loss LG amounts to

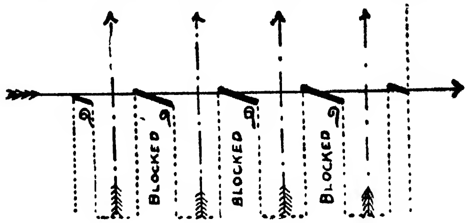


FIG 15:

3ft., this still leaves 12ft. (TL) to pass per unit of time, when the leading edge comes round again to its original starting point. This portion, which has to be destroyed by striking against the leading edge of the blade, is shown shaded in Fig. 14. The backward stream of water encounters no resistance, but runs away freely so long as the screw blade is not there to hinder it doing so, but when this current, running at 12ft., has to crowd itself and pass the leading edge of the following blade, which only allows of TF, equalling 8ft., there arises a series of concussions in the water, or vortices, which means a loss of power and speed, which loss has been devoted to the destruction of work already done by the driving side of the screw propeller blade.

But no screw propellers are used with a single blade, except by accident, and the illustration Fig. 15 is designed to show what really takes place when there are four blades to the screw. The diagram shows these four blades developed from a circular to a straight projection, and here it will be seen that the area of discharge from this screw propeller is divided into two nearly equal parts. The currents are designated by four arrows, which pass centrally through the four clear spaces, where there is nothing to hinder the backward stream of water passing away at its proper velocity. But where the little spirals are shown (in Fig. 15) at the back of the leading edges of each blade, there the backward stream gets broken up into a confused multitude of eddies and curls and spirals, showing conclusively that a considerable loss of efficiency is represented there. With such an arrangement as shown by Fig. 15, and bearing in mind the description already given, it will require very little penetration to see that such a screw would acquire a positive advantage by the removal of two of its blades.

This is a feature of screw propulsion which, with the popular theories on the subject, would be hard, if not practically impossible, to explain.

Example of Coarse Pitch.

Fig. 16 represents the conditions under which a substituted screw of coarse pitch would work on the same ship under similar conditions. Here

the screw blade AB is set at 40 degrees to the plane of rotation VT, which gives a pitch TF, equalling 19ft., the screw propeller being 7ft.

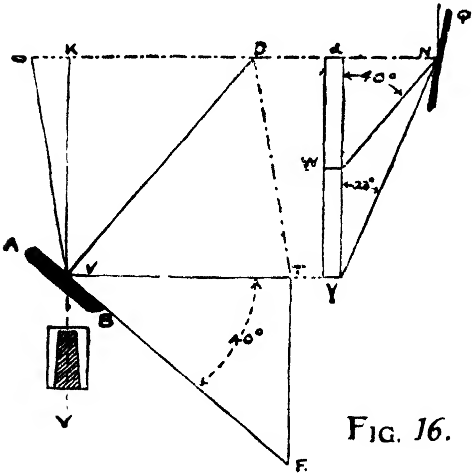


Fig. 16.

diameter, and its circumference 22 feet. TF, however, is not the correct measure of the current passing through the screw each revolution, but, according to Fig. 16, this movement is KV or dY, equalling 22ft. If, out of this, the ship travels 11ft. forward per revolution of the screw, the water current will travel backwards 11ft., and the angle at which the current runs backwards, while really dWN, equalling 40 degrees, is only dYN, equalling 23 degrees, relative to the ship, and to any observers who may be testing results on board.

As, however, there are no suicidal resistances within the screw itself, this apparent slip of 50 per cent. shows a far better economical working than the screw illustrated by Fig. 13, with its short pitch of 8ft. and no "slip" at all.

Whether, therefore, by purely theoretical construction of diagrams, such as Figs. 13 and 16, by unassisted practical experience, by experimental research, or by the elaborate Admiralty experiments conducted by Mr. Froude, we always arrive at the same conclusion, namely, that the best practical inclination of a screw propeller blade should be at about 40 degrees to its plane of rotation, and this will give better results than any other proportion.

Centrifugal Action.

With high-speed screw propellers centrifugal force is one among the chief causes that modify the forms of screw propellers, at any rate so far as the pitch of their outermost radii is concerned. As the blade travels across the direction in which the vessel moves, a transverse element is imparted to the current driven backwards, but this is not to be measured as the circumference. If, for example, the screw be 3ft. 6in. diameter, its circumference will be 11ft., and by using the diagram Fig. 16 it will be seen that the transverse element per revolution is dN, or 4ft. 6in., about .4 of the real circumference, and the figure upon which the centrifugal force may be calculated. The extreme effect of centrifugal force may even go so far as to create a hollowness or "cavitation," and this difficulty is usually met by sloping the screw blades backwards, as originally proposed by Lord Dundonald in 1843, and now carried out by makers of quick-running screw propellers. The calculations in connection with centrifugal force are of so complicated a nature that the best proportions of this class of screw have to be ascertained by actual trial and experiment.

Guide Blades.

So much has been done to improve screw propellers that there seems little room for further development in that direction. A new departure, therefore, has been found in the guide blade propeller, which receives from the rear column of water the power that has been expended in producing its rotation. With screws of short pitch, this rotation is very small and confused, as may be seen by dM in Fig. 13, but it increases considerably with increasing pitch as until dN is reached in Fig. 16. It has already been shown that screws of short pitch destroy all continuity of stream, and send back a confused mass of broken water, but this evil does not arise with screws of coarse pitch, such as illustrated by Fig. 16. Here the distance dN is considerable, and we find the interesting conjunction that the best form of propeller when working alone is also the best for giving back, through the guide blades, the power expended in producing a rotation of the rear column. Referring again to Fig. 16, it has been seen that the rear stream is set in rotation by the distance dN in every revolution, and that the inclination of the current in relation to the ship is 23 degrees, and thus the

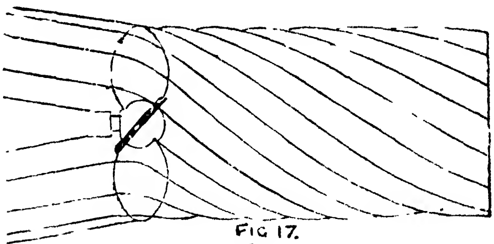


Fig. 17.

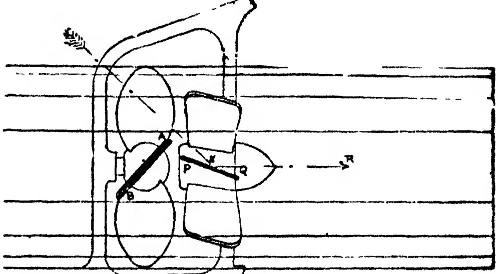


Fig. 18

general appearance of such a current is shown by Fig. 17. There the stern lines of the ship exercise an influence as to the inclined direction in which currents enter the screw area, and this influence is retained, in combination with the rotation given to the column of water driven backward by the screw.

Now if we fix into this rotating column another screw propeller, of reversed and very much prolonged pitch, one blade of which is shown by P Q in Figs. 16 and 18, the streams of water will strike against it at N (Fig. 16) or X (Fig. 18), when the adjustments are properly carried out, and so give back to the vessel the power which has been lent for producing this rotation. Fig. 18 illustrates the whole arrangement more clearly. Here A B is one screw blade, and P Q one of the guide blades set at 11 degrees to the line of screw shaft. The bent arrow represents a single item of stream of water striking upon P Q at X, and reflected by the blade P Q into the direction X R, or due aft. Thus, the pressure on P Q gives a resultant, which increases the towing or driving power of the engines. That a considerable gain of pressure ensures from this arrangement is shown by the following table of dynamometer readings :—

Haulage.	Tow rope attached to post Haulage I.	Towing two loaded barges. Haulage II
Screw alone ..	480 lb	From 480 to 540 lb
Screw and blades	660 ,,	,, 750 ,, 780 ,,

Except the addition of the guide blades, none of the conditions were changed. The tug being very heavily loaded, a peculiarly good example of the advantage of guide blades was furnished. The screw propeller of this tug boat was a very good one, its blades being set at about 41 degrees to the plane of rotation, and the return of nearly 50 per cent. gain by the application of guide blades, represents probably the maximum that can be expected from them. The minimum end of the scale would occur with such a screw as represented by Fig. 13, with its short pitch. Under such conditions neither the screw alone nor in combination with guide blades would do a good performance, both being worked under the most disadvantageous conditions.

This guide blade system, with a slight modification for higher speeds, has been used by Messrs. Thornycroft for their shallow-draught vessels. Five of these large steamers, 140ft. long, 21ft. wide, and 1ft. 9in. draught of water, were built by them for the Nile Expedition. Each was propelled by two guide blade screw propellers, 32in. diameter, and in the measured mile test they give $15\frac{1}{4}$ knots per hour.

The original investigations on guide blade screw propellers were made on a boat 4ft. 3in. long, provided with a clock spring which was always wound up to the same stop, all experiments being conducted by the same power. The screw and guide blades were made out of a model turbine, and are shown in Fig. 19.

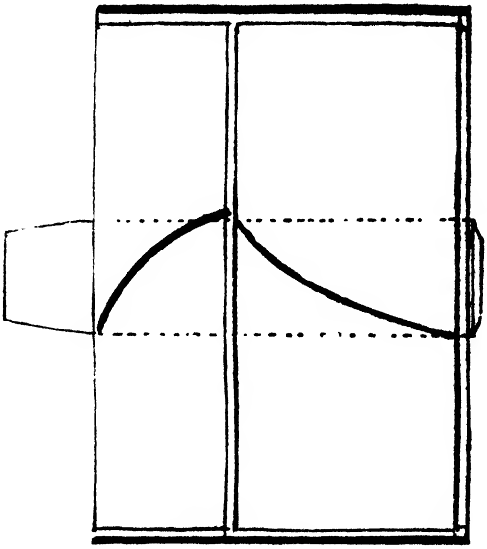


FIG. 19.

The following tests were made by this model on September 30th, 1863, the run in each case being 2min. :—

With the screw alone .... 100ft. 5in.
With guide blades and surrounding tube .... 112ft. 0in.
With screw and guide blades. and no tube ... . 122ft. 0in.
With screw and tube, and no guide blades .... 40ft. 0in.

Thus it would seem that further improvements in the performance of screw propellers are less to be expected from any changes in the screw itself than in the direction of guide blades, constructed on lines of scientific accuracy, and based on a sound and true theory of screw propulsion.

THE DESIGN OF SCREW PROPELLERS.

The propulsion of vessels by power developed within the vessel always takes place from the projection of a mass of water in the opposite direction to that in which the vessel moves, and is, in accordance with Newton's third law of motion, that "action and reaction are equal and opposite in direction."

This statement does not apply to the case of ferry bridges or to models propelled by rockets, though the principle above mentioned is still applicable.

Action and Reaction.

The action or thrust of the screw is ultimately obtained by delivering water astern at a higher axial velocity than that at which it is received. If A equals the area in square feet of the column of water thrown astern, and V equals the velocity in feet per second of its approach to the screw, and S equals the increase of its velocity in delivery from the screw in feet per second, then the quantity of water operated on in cubic feet per second equals $A \times V$, and its mass equals $\frac{w}{g}AV$, where w equals weight in pounds per cubic foot of water and g equals the acceleration due to gravity in feet per second. The action and reaction on thrust are measured by the momentum imparted to the sternward moving column, which is represented by the product of the mass into the increase of velocity, and therefore equals $\frac{w\,AV}{g} \times S$ lb., or equals $\frac{W}{g} \times S$ lb., where W equals weight of the volume AV.

The power available at the propeller is divided into two parts, viz., that which produces the motion of the vessel and that which is lost by increasing the velocity of the water through the propeller in the opposite direction, or by adding to it that velocity which is commonly spoken of as the slip. The slip of the propeller is the difference between the advance of the screw when supposed to be working in a solid medium and the advance of the vessel, in units of feet and seconds.

It follows, therefore, that of this fixed quantity of energy given to the screw by the machinery, the reaction or thrust already given as $\frac{W}{g} \times S$ can be maintained constant in value, either by increasing W, the weight of water acted upon, and decreasing the slip (S), or by decreasing W, and increasing S inversely. Since energy is measured by the product of a force into a distance, we have the two parts just referred to represented by $\frac{WS}{g} \times V$, as that absorbed by the movement of the vessel, and $\frac{WS}{g} \times S$ as that lost in the water thrown astern; the sum of these two quantities equals the constant amount given out at the propeller, viz., $\frac{WS}{g} \times (V+S)$. Again, as we have made the reaction constant, consequently the factor $(V+S)$ is also constant, which implies that, by diminishing the slip (S), the velocity of the ship would be increased. Turning to the factor representing the propelling force, it appears that the smaller S becomes the greater W will become, or the larger the body of water thrown astern at the lower velocity the more effective the propulsion and the greater the speed of the vessel.

Influence of Form of the Vessel.

These remarks apply to a propeller, which must be assumed to be so far behind the vessel that the feed water is uninfluenced by the wake (i.e., by the movement of the water in the direction of the vessel's motion, caused by the filling up of the cavity left by the stern), as also by the water set in motion by the skin friction or rubbing of the sides of the vessel, and again by the position of the stern relatively to the wave slope, as the orbital motions of the water particles are in opposite directions at the crest and hollow of the wave. When the propeller is brought to its usual position at the stern, it generally works in water which has a velocity, relatively to still water, in the direction of the vessel's movement, and consequently the velocity of feed to the propeller is diminished, and, with it, the delivery astern is less, relatively to still water, so that the slip as measured by the difference between propeller and ship advance, as described before, becomes less, and is known as the apparent slip, as distinct from the true slip.

This forward movement of the wake may become so great in vessels with a full stern, associated with screws of very fine pitch, as to cause what is called negative slip, a condition of things which makes it appear that the vessel is out-travelling the screw. In such cases the performance is a bad one, and could generally be remedied by an alteration to the stern and also the screw.

Reverting to the theoretical conclusion previously arrived at, that a large body of water thrown astern at the lowest velocity or slip would

give the most efficient result, this would point to the propeller of largest diameter being used, but it should be remembered that this is generally limited by the draught, and, therefore, the pitch would have to be increased with diminished efficiency.

Loss by Friction.

Another element not accounted for in the investigation is the loss by friction of the propeller, which is dependent on the amount of surface, and particularly by the circumferential velocity of the blades; the loss of power by the latter element is something probably approaching the cube of the speed, similar to that due to skin friction of ships, which varies as the 2.83 power of the speed, or as $V^{2.83}$.

Investigations, therefore, upon the efficiency as outlined at the commencement have to be materially modified, and the rational results can only be arrived at by resort to experiments such as those carried out by Mr. R. E. Froude for the Admiralty, and by Sir John I. Thornycroft, Mr. S. W. Barnaby, Mr. Yarrow, and others. In most of these cases the experiments were carried out in water undisturbed by the elements of frictional wake and form of stern, the propellers being of standard form and of uniform pitch in the Admiralty experiments, and of a standard form peculiar to the other experimenters with increasing pitch. The results arrived at established a range of pitch varying from .8 to 2.5 times the diameter, with efficiencies varying between .63 and .69, which gives considerable latitude in the choice of a propeller.

In designing a propeller, however, it is very important to know the value of the wake factor, as this determines the velocity of feed, which has been already explained to be different to the velocity of the ship, and much data from actual ships in which the performance of the propeller is associated with the form of the stern is needed, and for this reason the method of fixing the slip (using the word in the common sense) of a required propeller according to the class of ship on which it is to be used is still the common practice.

Influence of Vessel's Speed.

It is frequently imagined that motors giving the same B.H.P. at the same revolutions per minute require always the same propeller and that they will be correct for any type of boat they are placed in; but this is not the case, as the same power applied to boats of different dimensions and form will give different speeds, and to use the same propeller under these conditions would give very different values of slip, for each of which there is a different efficiency. The diameter may be also materially affected, the slower moving vessel requiring a larger propeller than the faster one of the same power and revolutions.

For example, with screws of the same pitch ratio (i.e., $\frac{\text{pitch}}{\text{diameter}} = \text{constant}$) and working at the same slip, the horse-power is proportional to the disc area of the propeller multiplied by the cube of the speed of the ship. Expressed in symbols H.P. varies as $A.V^3$, where H.P. equals horse-power, A equals disc area, and V equals speed. Now, taking two vessels of different weights and form and for which the same power should drive one of them twice as fast as the other, then in the faster boat the value of V^3 is eight times that of the slower boat, and, consequently, the value of A must be ⅛th that of the slower boat, so that the diameter, which varies as the square root of the area, will, therefore, be $\sqrt{\frac{1}{8}} = \frac{1}{2.818}$ or nearly one-third that of the propeller for the slower boat. For the above reasons, with boats of different sizes and shapes, different propellers are required with the same motor.

The thrust per unit area increases as the square of the speed, since AV^3 or $AV^2 \times V$ is proportional to H.P., of which expression AV^2 is proportional to the thrust, so that, as V^2 is increased, A is decreased inversely, and this may demand an increase of blade area above that of the experimental standard form to prevent the occurrence of the phenomenon known as cavitation.

Form of Blades.

The blades should be worked off very fine at the edges as indicated at A (Fig. 1), as if very thick on the forward face as at B there is a certain amount of sternward thrust delivered to the blade. Experiments conducted by D. W. Taylor, of the United States Navy, have shown that the efficiency may be increased from about 69 to 78 per cent. by making the edges of the blade sharp and the section thin; at the same time, sufficient regard must be paid to the strength of the blade.

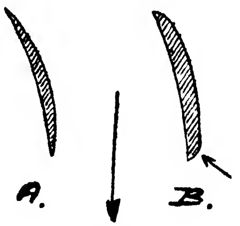


Fig. 1.

In early high-speed boats the blades were nearly of constant width, thrown back towards the tips as shown in Fig. 2, but now that far higher powers are used and higher speeds are obtained, which have a tendency to reduce the diameter, a much larger fraction of the disc area becomes necessary for the blades. In the case of the standard propellers used in the Froude experiments the shape of the blades was elliptical (Fig. 3), with one end of the major axis at the tip of the propeller and the inner end being occupied by the boss, which is not available for propulsion. When more

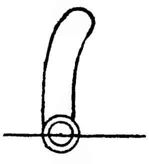


Fig. 2.

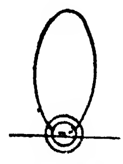


Fig. 3.

area is required, this shape may be considerably departed from, and in vessels of the mercantile marine the width at the tips is generally greater than at any other part of the blade.

As regards the fanciful shapes of blade frequently put forward as possessing superior advantages over the usual and ordinary kinds, the fact remains that the large commercial interests and the Admiralty adhere to the simple forms of which they have had abundance of experience.

The Propeller Shaft.

The inclination of the propeller shaft relatively to the water plane should be as small as possible, as the effective thrust in the direction of motion is thereby increased, and in cases where the inclination is considerable vibration is set up, owing to the relative change of pitch to the horizontal motion of the vessel at every point of the revolution. For, though the pitch of the propeller in itself is unaltered, the angle of the blade, referred to the direction of advance of the vessel, is different at every part of the revolution.

The outboard length of shafting in cases where the deadwood is cut away to save weight, to reduce surface friction, and to increase the steering capabilities, as in many racing boats, is a matter which requires careful attention, particularly where the revolutions are very high, as the tendency of the shaft to whip (or bow) between its end supports after the manner of a skipping rope may cause fracture. This tendency is aggravated by the thrust from the propeller, which is in the line of supports (i.e., propeller brackets and stern tube), not being along the axis of the shaft itself; the shaft then becomes subject to a thrust and to twisting and bending moments, the latter being likely to cause failure. Shafts should, therefore, not be too light, but sufficiently stiff in relation to their length to prevent whirling. In extreme cases where the shaft would become too heavy, an intermediate support is necessary.

Shaft Supports.

The brackets carrying the propeller shaft when there is no deadwood require careful designing, as in the case of a propeller blade being carried away by striking some object in the water the unbalanced centrifugal force may become very considerable. This force varies with the disturbing weight, with the distance of its centre of gravity from the axis of rotation, and with the square of the number of revolutions per second. An example will suffice to illustrate how much this force may become in a small propeller at a high number of revolutions.

Suppose the diameter to be 20in. and the weight of the blade carried away to be 4lb. and its centre of gravity to have been 6in., or .5ft. from the centre of the shaft, and the number of revolutions 1,000 per minute, or 16.6 per second, then, by the law of centrifugal force, the unbalanced force through the centre outwards and opposite to the position of the lost blade

$$= \frac{4\text{lb.}\ (2\pi \times 16{\cdot}6)^2 \times {\cdot}5\text{ft.}}{g(= 32{\cdot}2)} = 685 \text{ lb.}$$

This force, acting on alternate sides of the bracket 1,000 times per minute, would be sufficient in most cases to break or tear away a single armed bracket, and points to the advantage as regards safety in the use of two armed brackets of the V type (Fig. 4).

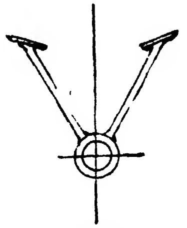


Fig. 4.

In extension of the foregoing, the importance will be seen of perfectly balancing the propeller, for if the excess of weight of one blade over each of the others be one-eighth of a pound, then, under similar conditions to the above, the unbalanced force would be 21.4lb.; this force would be felt laterally and vertically 1,000 times per minute, causing considerable vibration and discomfort, rapid wear of the shaft bearing, and opening of the joints in the planking of wood boats.

The pitch of each blade should be identical, as any difference tends to set up vibration due to another cause; and the surfaces should be polished and as smooth as possible.

Propeller Boss.

The general practice for neatness appears to be to reduce the diameter of the boss to a minimum; this has the advantage in small boats of reducing the weight of the propeller, and is apparently the only one, as it has been advocated long ago by Griffiths, and since his time, that a large boss is desirable and for reasons which are sound. The pitch of the screw, which may be assumed to be constant from the boss to the tip of the blade—which means that a convolution at any particular radius extends the same length along the axis—has a different pitch angle at each radius.

To explain this, reference is made to Fig. 5. Let a b represent the pitch or the distance along the axis traversed by any radius on the screw in

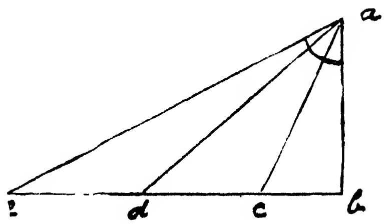


Fig. 5.

one complete turn, then for equal angles swept out by the rising radius arm, equal heights will be traversed along the axis, i.e., along a b, so that the development of the line traced by each radius, which upon the cylinder would be spiral, becomes a triangle, the base of which (b c, b d, or b e) would represent the circumference of the cylinder at each particular radius, with the

constant height at b, which represents the pitch. The angle, therefore, which the blade makes with the axis (a b) is (b a c), (b a d), and (b a e), so that the nearer the section to the centre of the propeller the smaller this angle, as b a c, becomes, and if the blade could be extended to the axis, the angle becomes zero and the blade directly fore and aft, which means that the water at this point, instead of being thrown astern and contributing to the propulsion, would simply be thrown out transversely and a churning effect produced, with great waste of power.

In the case of reversing propellers the large boss remains as one of their advantages, together with the equally important one from a mechanical point of view, viz., the opportunity it affords of amply securing the blades, which are so peculiarly liable to damage.

As reversing propellers have been referred to, it may be remarked that for small powers they offer a very convenient means for effecting their purpose, as implied by their name, but for large powers they are not so suitable, as if the reversing mechanism be damaged they cannot be dealt with while afloat, whereas an ordinary propeller, which is not so likely to be deranged and is governed by a reversing gear in the boat, can be attended to at any time.

Form of the Boss.

The next point claiming attention in respect to the boss is the abruptness of entry or delivery of water to or from the propeller.

It has been demonstrated that in the case of well-formed, regular bodies, completely submerged, as torpedoes, for instance, the principal and only practical resistance is the frictional one (this, however, would be negligible on a propeller boss). The stream lines caused to diverge at the head return the pressure again to the

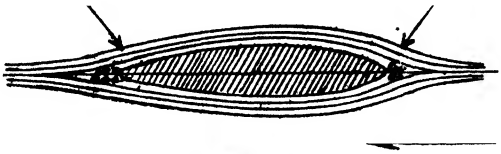


Fig. 6.

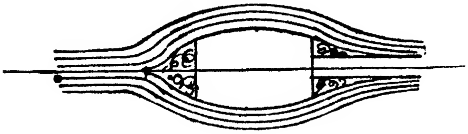


Fig. 7.

body as they converge at its tail, and this without much reference to the relative form of the fore and after bodies, provided the after end be not too short. The stream lines would be somewhat as indicated in Fig. 6, the arrows showing the pressure tendencies. If the fore end of the boss be abrupt, as indicated in Fig. 7, the water is suddenly diverted and an eddy formed, and the same applies to the closing in of the water at the after end; in each case a loss is experienced which is equivalent to an augmented pressure at the forward end and a loss of pressure at the after end. The effect is somewhat analogous to, though not so accentuated as in the case of, towing a brick through the water, and the higher the speed of the vessel the more serious the result.

The importance of making both the entrance and the after body of the boss easy is borne out by the adoption of long cone bosses in torpedo-boat destroyers, and particularly those of the steam turbine type, at very high revolutions and great power, as also in the most successful motor racing boats in this country and abroad. At very high revolutions the centrifugal force reduces the pressure on the boss and increases the necessity for this long cone termination to recover the loss in aid of the thrust.

Stern and Rudder Posts.

Associated with the foregoing, relating to abruptness and continuity of surface, and for which the performance of the propeller is frequently blamed, is the broad square stern-post in front, and the similar rudder-post aft of the propeller and in close proximity thereto. Unless

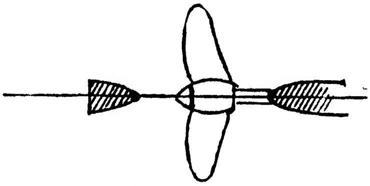


Fig. 8.

these bodies are comfortably eased off as shown in sectional plan (Fig. 8), the propeller encounters a serious eddy in the first case, and in the other the delivery is seriously obstructed.

These remarks apply to cases where the deadwood is not cut away, and particularly to auxiliary yachts in which the propeller, driven by a motor of small power, has the greatest portion of its effective area reduced by these parts where a two-bladed propeller is employed. When in the fore and aft mid-plane two-bladed propellers are completely masked, and whatever water is thrown astern is delivered directly on to the rudder-post, annulling a great proportion of the propelling effect and setting up vibration.

In the case of auxiliary yachts, a larger diameter of propeller should be used, with finer pitch, in order to get more effective area into unbroken water.

Similar remarks apply to cases where the deadwood is cut away and the propeller works in unbroken water, but where the shaft emerges from the boat through a solid block which carries the stern tube, abruptly ending in a section of something like 6in. by 5in., which adds additional drag to the boat, in such cases it is an advantage to add a cone (Fig. 9), allowing the water to fall easily to the shaft.

Similarly, in cases where the keel is intended to protect the propeller when the boat takes the ground, as in Fig. 10, the sections along lines

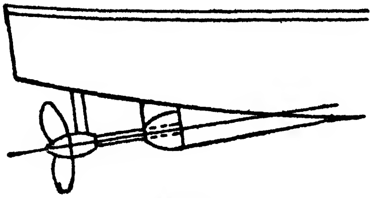


Fig. 9.

parallel to AB should be worked off gently, as shown in the shaded part of the section, and not allowed to end squarely. These remarks apply

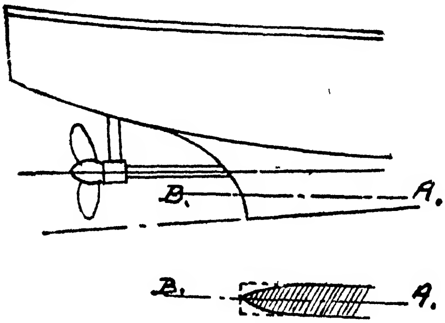


Fig. 10.

to the boat only, inasmuch as they tax the performance, and, therefore, the propeller, indirectly.

Depth of Immersion.

The propeller should be sufficiently immersed so as not to break the surface and take air down with it, or its efficiency may be greatly impaired. A number of inventors have sought to reduce the skin friction of vessels by separating the underwater portion of the hull from the water by means of a film or cushion of air, but the advantage thus gained is immediately lost by the propeller having to work in water that is mixed with large quantities of air.

Effect of the Rudder.

The position of the rudder in relation to the propeller when forward of the same causes considerable disturbance to the feed water and of the performance of the propeller when moving ahead, whereas when placed astern the disturbance is less and the steering effect greater, and a smaller amount of helm is required on account of the higher speed of delivery on to the rudder, while the speed ahead is not so much checked. In moving astern when the rudder is behind the propeller, as in most boats, the movement of the boat is much affected, for when the helm is hard over the flow of water is such that one-half of the propeller is working in an eddy, as in Fig. 11, and in all cases the boat steers better astern on one side than the other, viz., with right-handed screws when the helm is to starboard, and vice versa with the left-handed screws. If the screw be enclosed by duplicate rudders, as in Fig. 12, then the astern movement is very much improved, as it is enabled to draw freely on a comparatively undisturbed flow of water, and steers equally well on either helm.

Among other causes which contribute to a boat having to carry helm on a straight course

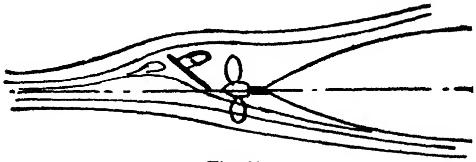


Fig. 11.

when moving ahead may be mentioned that the lower blades work in water under greater pressure than the upper ones, so that the pressure on the rudder in the fore and aft plane is greater on the one side than the other. The next cause is due to the resistance of the water to the rotation of the propeller, producing a reaction which can only be balanced by a corresponding heel of the boat, and particularly so in the case of high powers associated with small beam, and the effect of this heel on the course of the boat has to be corrected by carrying a corresponding amount of helm. In the case of twin screws rotating in opposite directions the above elements are cancelled.

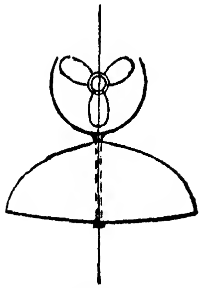


Fig. 12.

Vibration.

A few additional remarks may be added on vibration as affected by the number of blades of the propeller.

With two-bladed propellers the blades come into the same plane as the stern-post twice per revolution, administering a shock each time; with the four-bladed propellers this happens four times per revolution, and in each of these cases two blades are casting water on to the stern post. With three-bladed propellers the shock happens six times, but each time only with one blade, so that the vibration, although intermediate in periodicity, is only one-half in effect as regards the shock. In cases where the stern-post is absent there can be no difference between propellers with different numbers of blades so far as vibration is concerned, though probably three-bladed propellers are the most generally satisfactory.

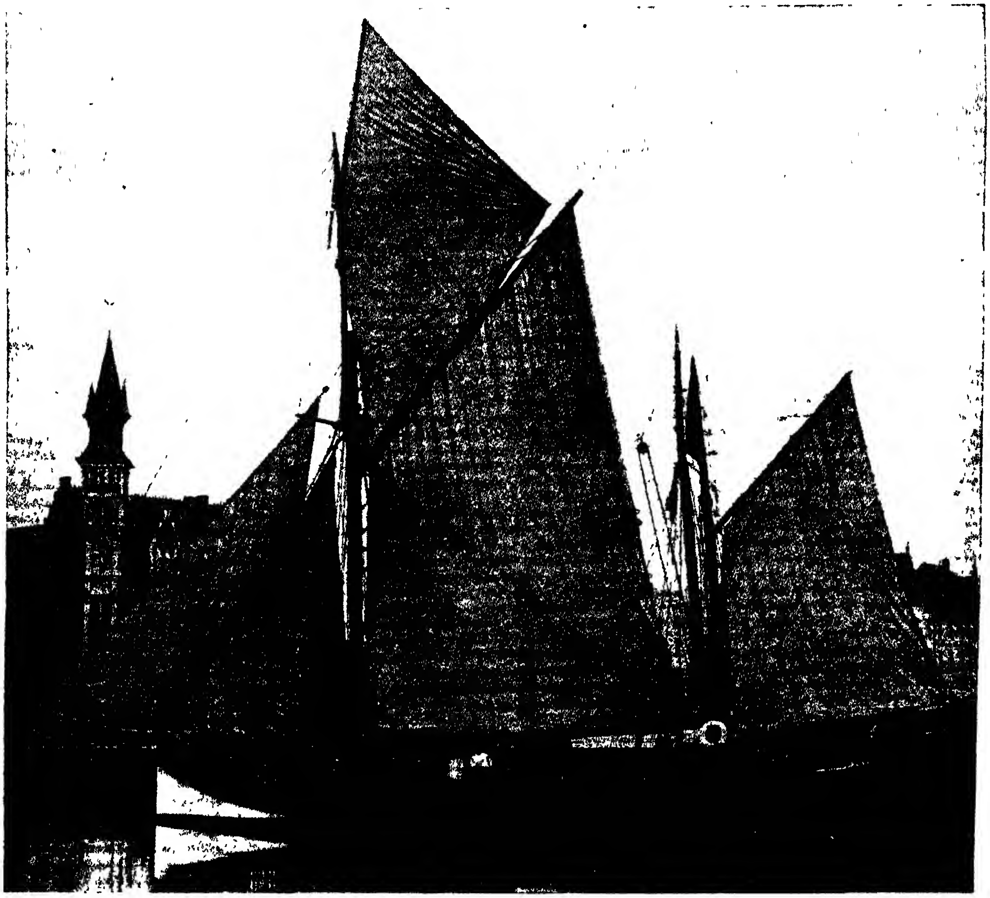
Ordering a Propeller.

When a propeller is required for fitting to an existing boat, very full particulars of all the conditions should be given. From a perusal of the foregoing article on its design, it will be realised upon how many influences the success of a propeller depends, and it is only in a full knowledge of all the conditions that a designer can hope to obtain first-class results.

The particulars which are absolutely necessary are as follow :—The length and beam of the vessel at the water-line; the draught of water (without the keel) amidships, and the maximum draught if greater at any other point; the horse-power of the engine and its speed of revolution per minute; whether the propeller is to be right or left-handed; the distance between the shaft and the bottom of the vessel, or between shaft and the protecting bracket below it (whichever is the less); and the diameter of the shaft. In addition to these, and if possible, give the displacement of the vessel, and drawings showing the form of the after part at least.

Right and left-handed propellers refer to the direction of rotation *when driving ahead.* Looking at the stern of a vessel from aft (i.e., facing forward), a right-handed propeller is one which turns in the direction of the hands of a clock ("clockwise"), and a left-handed screw revolves in the contrary direction ("counter-clockwise"). It is very important to state which is required, for, in the absence of information, the propeller manufacturer, or supplier, is likely to assume that the direction of rotation is as usual —which it may not be. We have several times had cases before us where a left-handed propeller has been supplied when a right-handed one was required.

The balance of a propeller is a very important feature, but one that it frequently neglected by all but the highest class shipbuilders. If a new propeller has been purchased it should always be tested for balance.



"L'Avenir," a motor auxiliary lobster carrier.

VIBRATION ON MOTOR BOATS.

Of all the troubles connected with a seafaring existence, especially in a high-speed boat, none can be greater or more persistently troublesome than vibration. Its effects have long been known, but its causes have only been the subject of comparatively modern investigation. They may, however, be conveniently catalogued in two classes, namely:—Class A—Vibrations occurring in the region of the screw propeller. Class B—Vibrations more or less directly connected with the engine. The general effect of vibration is to convert the whole vessel into a rude form of musical instrument, where, however, discords generally prevail! The fundamental note, however, of this instrument is produced by such slow or infrequent vibrations as to be far below the powers of our auditory nerves to appreciate.

Vibration at Propeller.

To deal first of all with Class A, so far as the screw propeller itself is concerned, most makers understand, if they do not always practise their knowledge, that the screw must be accurately balanced so as to obliterate any irregularities that might arise from an unbalanced mass revolving at high speed. When this condition has been properly cared for, any vibration occurring towards the stern of the boat can be credited to one or two general causes. The simplest of these arises from the oblique or transverse direction in which currents driven backwards strike against the rudder or rudder-post. These currents, dashing volumes of water against the rudder, or its post, create a shock whenever a blade is passing the rudder, and this cause is at its worst with two or four-bladed propellers, as the shocks occur whenever two of its blades stand vertically. This evil becomes considerably lessened with three-bladed screws, or by enlarging the space behind the screw, and reduced, most of all, by the more modern types of boats, which are not provided with rudder-posts at all. Of course, twin screws have a free discharge for the stream of water driven backwards; and they are, therefore, free from liability to drive any currents transversely against the rudder or rudder-post.

Vibration of Engine.

The second cause of vibration (Class B) is of a more recondite nature, relating as it does to rapid movements that may be originally set up by the engine (which, for present discussion, may be assumed as being fixed in the boat, at about the middle of its length). Such vibrations may become more violent in some places than in others, or at certain speeds as compared with others, besides having nodes, where there is an absolute state of rest. Thus, problems connected with vibration, its cause, or causes, and cure, present a very tolerable crop of difficulties, only to be overcome by taking each in turn, beginning at the very beginning, and regarding the boat as if it were a single solid rod of steel; that is, solid in relation to its longitudinal strength, and provided with numerous attachments, or ribs, which serve to create numerous discordant sounds, each, as it were, providing its own share of the concert.

Boat Regarded as a Rod.

If, then, we choose to regard the boat as a rod of steel, and, for the moment, pay no attention to any other details, and if we remember that vibration always implies a musical note, we can

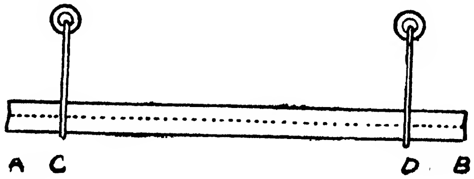


Fig. 1.

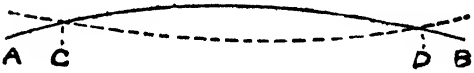


Fig. 2.

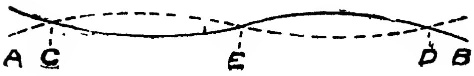


Fig. 3.

illustrate its action by comparing it with the performance of a steel rod, suspended in two places, such as it might choose for itself if floating in mid-air. The illustration (Fig. 1) shows the simple case of a steel rod (A B) suspended from the points C and D, and so arranged that A C = D B = one-eighth the length of the rod A B. This rod, so supported, will give a musical note with good harmonics when struck between C and D, and the condition when

in vibration, and giving its fundamental note, is shown by lines on Fig. 2. Of course, the diagram is greatly exaggerated so far as the curves are concerned, but it is only intended to illustrate the principles and not the proportions of a vibrating rod, having heavy vibrations at the middle, and extremities, with nodes, or positions of no vibration, at C and D, which corresponds with the action of this same class of fundamental note of the combination on board ship—or boat. In addition to the fundamental note of the steel rod (Fig. 1) when struck, there are numerous harmonics, or overtones, which are illustrated in Fig. 3. Here, the length of the portion set in vibration is reduced by one-half, the number of vibrations is doubled, and the overtone given is an octave higher. This intermediate node, at the point designated by E, shows where this node occurs with corresponding absence of vibration. All these harmonics are independent of and can be heard along with the fundamental note, and in music they constitute a great part of its beauty. In a boat, however, they produce an effect like the discordant voice of a bad singer, where his overtones harmonise neither with his fundamental note nor with each other. Pushing the analogy further, and regarding each part of the boat as producing many vibrations, each possessing its own musical (or unmusical) note, is it a matter for wonder that these vibrations, not being multiples of each other, and differing as to their fundamental note and harmonics, should produce a discordant assemblage of sounds, that can only be described as noise! It might be worth while to ascertain whether a good musical sounding beat could not be produced. A piano, a bell, or any other musical instrument, requires tuning, so why not a boat? If such a boat, so tuned, could show a harmonious chord, it might be much pleasanter to sail in than one producing a discordant note, because the effect on the nerves would be less irritating. Indeed, the accidental arrangement of parts, so as to harmonise in this manner, may be the reason why boats, and large ships also, are in some cases pleasanter to sail in than vessels where no such conditions prevail.

Corresponding effects of vibration can very well be seen by suspending a polished steel plate, horizontally, like Fig. 1. By scattering sand over its surface, and producing a note by friction, the grains of sand run to the nodes, or away from them, and the positions of these nodes vary according to the place where the friction is produced, and the direction of vibration given. This experiment illustrates, in a very beautiful and simple manner, the conditions of vibration which occur on a very much larger scale.

If now a new and powerful cause of vibration be introduced, such as an unbalanced engine in rapid movement, the confusion increases. Sometimes the fundamental notes are disturbed, and in the reigning confusion imagination is completely baffled in any attempt to unravel the combination. At other times this new cause for producing vibration increases the amplitude of some excursions belonging to certain of the vibrators while diminishing others, thus producing another variety of inharmonious sounds.

Production of Vibration by the Screw Propeller.

If now we assume that the screw propeller has been properly balanced, the effect of currents driven obliquely backwards may be diminished, if not entirely removed, by providing a large space behind the screw. This is frequently done, even in large vessels, to facilitate the replacement of a screw propeller without moving the engine shaft. In modern boats, however, such as have no rudder-post, there is usually ample room for the cross currents to get away freely.

When a screw propeller has only a few inches of water above it, there remains only the atmospheric pressure of 15lb. per square inch available to force a supply of water into the semi-vacant space in front of the screw. Where an excessive speed of rotation forms part of the design it happens, not infrequently, that a deficiency occurs in the matter of supply, and with it a corresponding loss of efficiency. This evil has been called "cavitation," and it is a thing to beware of in arranging the proportions of screw propellers. After all, the screw is only a rather bad pump, and one that requires a very considerable amount of water to keep it supplied, so that when cavitation prevails it becomes a very present and rather unsuspected cause of vibration.

Production of Vibration by the Engine.

There are three general causes which tend to the production of vibration by the engine, namely :—

(1) Centrifugal force of revolving bodies in connection with the engine shaft, such as cranks.

(2) Impact of explosions in connection with internal combustion engines.

(3) Reciprocation of pistons, connecting rods, valves, etc.

Centrifugal Force.

One of the essential laws impressed upon matter in motion is that no change can take place in the direction or velocity with which any body travels without the application of force, consequently, when a body travels in a circular path it continually deviates from the straight line in which it would move; falling, as it were, towards the centre. The natural direction would be tangential at any moment, and a restraining, or centripetal force is required to keep the body moving round a fixed centre. Its tendency to fly out is equal to the restraining centripetal force, and is called by the name of centrifugal force, which is really a resistance to be overcome by force applied from the outside.

The following information is necessary in order to ascertain the centrifugal force exercised by any body revolving around a centre :—

RULE.	ILLUSTRATION.
W = Weight of the body (in pounds) ...	1lb. in illustration.
N = Number of revolutions per minute	1,000 revolutions.
r = Radius in feet ...	.5ft.
F = Centrifugal force (in pounds)	170lb.

The following formulæ give centrifugal force :—

$F = W \times N^2 \times r \times .00034.$

In the illustration given,

$F = 1 \times 1{,}000^2 \times .5 \times .00034 = 170\text{lb}.$

This example illustrates how heavy may be the strain produced by even a small unbalanced item which gives here a pull of 170lb. reversed 2,000 times per minute. With the number of revolutions per minute doubled the centrifugal force increases four times, which shows that a weight of only 1lb. can provide a pull of 680lb. reversed 8,000 times per minute. If the motor in a boat were driven in such an unbalanced condition as this, the result would be disagreeable in the extreme; but such a thing can seldom happen, for one reason that several cylinders provide a sort of rough balance one against the other, and this prevents the pressures due to centrifugal force of any one cylinder rising too high. Fig. 4 illustrates the peculiar nature of the pull that is exercised by centrifugal force, acting as it does from every point of the compass, thus straining the foundation on which the main shaft rests, and showing also that the rotating pull due to centrifugal force may increase or diminish the strain due to the normal force upon the bearing.

As every piece of metal and every plank of wood that may be used in the construction of a boat has its own fundamental note, or amplitude of vibration, the coming in of an unbalanced centrifugal force introduces a power which can occasionally shake a large vessel from stem to stern, and as doubling the rate of its engine's revolutions quadruples these strains in magnitude (for centrifugal force varies as the square of the number of revolutions in any given time), it is most important to reduce these strains to impotence, and so to save power and to increase the comfort and convenience of the crew, and of the boat, the very life itself. The ultimate foundation upon which every floating body rests is the water, and its inertia is the last thing relied upon to give steadiness to the boat floating on its surface. Even if the unbalanced strains be spread out on a large superficial area they still amount to a heavy total, such as is often shown by the loosening of rivets and general demoralisation of the boat. Vibration is an evil all round, and the measure of the harm it does gauges the importance of providing means to remove, or at least to diminish, the intensity of its operations.

Remedy for Effect of Centrifugal Force.

As a body revolving around, and at a definite radius from the shaft upon which it is carried, serves as an example of the simplest form in which an unbalanced force can produce vibrations, so is the remedy for such an operation simple also. It consists in nothing more than applying another similar weight exactly opposite, and in the same plane, as shown by Fig. 5.

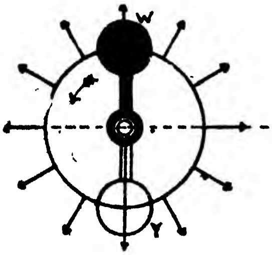


Fig. 4.

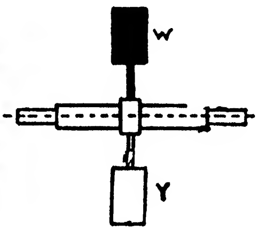


Fig. 5.

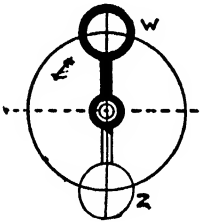


Fig. 6.

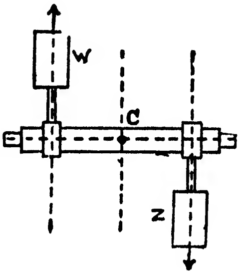


Fig. 7.

This arrangement is frequently seen in the cranks of engines, when a mass of metal (Y) produces an equal centrifugal force exactly opposite to W, and also in the same plane. Thus the two centrifugal forces balance each other, and quiet running is secured. If the balance weight (Y) be fixed at a different radius to that of the main weight (W), then the counterpoise must be reduced in the inverse proportion to the relative distances of each weight apart, as may well be seen in the balance weight fixed to the wheel of an outside-cylinder locomotive. These arrangements not only provide a static balance where the whole system stands in equilibrium at any position when stationary, but they serve also as a dynamic balance when the whole system is in motion and the centrifugal forces of the weight and its counterbalance are equal and opposite to each other. It is such a simple matter to make this class of balance that few large engines are unprovided with an arrangement of some sort, whilst, for high-speed engines, balancing the rotating part is an absolute necessity.

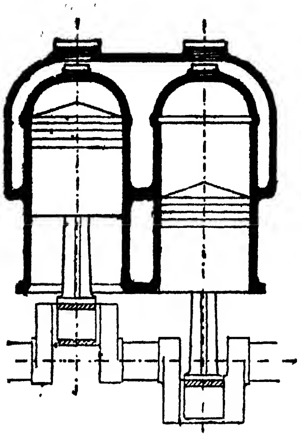


Fig. 8.

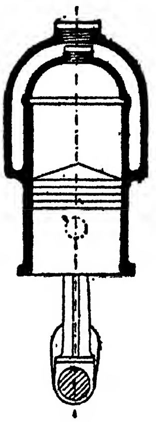


Fig. 9.

Figs. 6 and 7 represent a faulty arrangement of this counterbalance. Fig. 7 shows the balance weights working in different planes, and, although it quite correctly shows a static balance, it fails as a dynamic balance. Any pull developed by the weight (W) draws the shaft in its direction, while the corresponding and opposite centrifugal force due to the counterbalance (Z) draws the shaft in an opposite direction, and the result of this combination is what in mechanics is known as a "couple," which may be the cause of a serious rocking, ending in vibration. A common example of this class of faulty design is shown by Figs. 8 and 9, where the rapidly reciprocating parts induce a constant state of active vibration, the cause of which does not appear by any examination when the engine is standing still.

Mr. Yarrow's Experiments.

Probably the most complete series of investigations from a practical point of view were those conducted by Mr. Yarrow for ascertaining the causes and remedies for vibrations produced from the reciprocating pistons, valves, etc. Driving pistons, with cranks and connecting rods, were arranged by calculation and experiment so as to compensate by their reciprocation for such differences as remained over unbalanced, after the several sets of engines had compensated, as far as possible, for the combined action of all the reciprocating parts, and the result achieved was an extreme smoothness of motion and a lessened amount of vibration. These experiments are published in the proceedings of the Institution of Naval Architects.

Irregularity of Turning Effort.

A screw propeller may be regarded as offering a steady and uniform tangential resistance to the engine by which it is driven, so it follows that the latter should also show a steady tangential driving force. With an ordinary pair of cylinders constituting a single-acting petrol engine, with cranks opposite, such as shown by Figs. 8 and 9, worked with high rates of expansion, the maximum driving pressure usually occurs at about the middle of a stroke, and the driving of this particular class of engine ceases altogether while these cranks are passing over their dead centres. Consequently there is a series of impulses driving the screw, instead of a steady uniform force. This occurs, but in a somewhat lessened degree, when a fly-wheel is on the engine shaft. Such a mode of action is parallel to the case of a rower who gives a tremendous pull at the middle of a stroke of his oar, but slacks off towards the commencement and end, instead of giving a steady pull during the full length of a stroke, which every rower knows to be necessary.

In the case of a petrol engine, the evil of irregularity may, in some small degree, be compensated for by the high proportions its moving parts bear to the rate of expansion, but the best palliation of all is to have three or more cylinders all driving the same shaft: generally from three to eight cylinders are employed with such an arrangement.

With such high speeds as are usual with petrol engines, the movements of their comparatively heavy parts, namely, the long piston, with its end of the connecting rod, profoundly modify such pressures as may be shown on an indicator diagram, at every part of a stroke, both driving and exhausting, refilling with fresh air, and compressing according to the Otto cycle, and it is with these modifications that the engineer has to deal.

A Practical Example.

The following example will serve to illustrate a rather complicated subject. The data given are purposely exaggerated so as to make all the points clear, so it will be understood that they do not necessarily show points to be copied, and indeed in some respects the examples given can hardly be considered as good engineering practice at all.

Table of Data of Petrol Engine.

Internal diameter of bore of cylinder ...	...	6·9in.
Length of piston stroke	...	6·5 „
Radius of crank, 3·25in. or	...	0·27ft.
Length of connecting rod	...	13in.
Ratio of crank to connecting rod, 3·25 to 13	=	1 to 4
Weight of piston	=	15lb.
Weight of piston and half of connecting rod	=	25lb.
Centre to centre of cylinder	=	9in.
Revolutions per minute	=	1000
Area of cylinder	=	27·39sq. in.

Assuming the entire weight of the piston and half of the connecting rod concentrated around the crank pin = 25lb., then according to formulæ already given the centrifugal force

F = 25lb. × 1,000 × 1,000 × .27ft. × .00034 = 2,295lb. or per square inch of piston = $\frac{2,295}{27·39}$ = 83.4lb. (say) 84lb. Thus in the present example there would be about one ton tending to twist the shaft in every direction around the centre point marked C in Fig. 7.

Under such heavy strains no rigid resistance is possible, for there must be an incessant yielding of the shaft in every direction, as the weights revolve; and a series of violent strains become inaugurated which culminate in vibration, if they do not end in disaster.

The Question of Reciprocating Masses.

Thus it will be evident that the balancing of all revolving masses in connection with the crank shaft is a matter of easy accomplishment, but when the question of balancing reciprocating masses has to be considered, quite a number of complex problems arise. Some of these are negligible with engines running at slow speeds

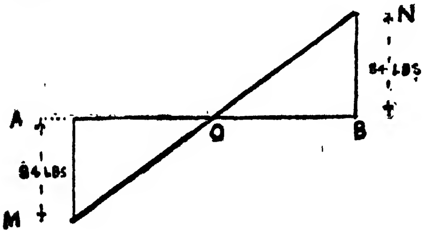


Fig. 10.

but all acquire great importance when regarded in connection with the high speeds demanded from petrol engines driving motor boats.

With all internal combustion engines, which necessarily deal with heavy initial pressures, it is fortunate that comparatively large, heavy pistons and connecting rods have to be used, for it is in consequence of the shock of explosion being so greatly absorbed in starting these heavy bodies from a state of rest that this class of engine is permitted to run so smoothly as experience shows it does; also it is fortunate that these irregularities can be designed so that in a great measure they compensate for each other. They diminish the excessive driving pressures of explosions, and they provide additional power just where it is wanted during the latter half of the stroke, to augment the diminished driving force due to the high rates of expansion and falling pressures which prevail with this class of engine. They also tend towards economy, smooth running, and absence of vibration.

This subject can best be approached by ex-

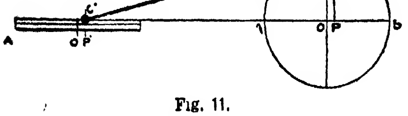


Fig. 11.

ample, and the figures typical of a motor already given (p.209) will serve this purpose well. In Fig. 10, A B represents the stroke of a piston, and A M = B N = 84lb. per square inch to any convenient scale, such as the corresponding engine indicator diagram might use. This 84lb. represents the centrifugal force due to the weight of piston plus, generally, half that of the connecting rod, as if concentrated at the crank pin. Absorption of pressure at A M diminishes as the

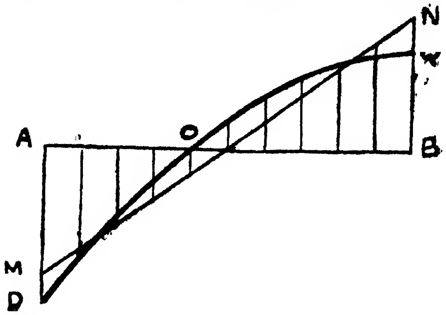


Fig. 12.

piston travels from A towards B, and when it arrives at O no further pressure is required for acceleration, as the piston has acquired its highest velocity In passing from O towards B this highest velocity of the piston is gradually retarded, and reappears in the form of pressure, until, at B, a maximum B N is reached (of 84lb. per square inch of piston) and the reciprocating parts are exercising this full pressure upon the crank pin, a crank which at B is on its outer, or lower dead centre. This elementary diagram shows no effect as being produced by the ratio of connecting rod to the length of crank, which

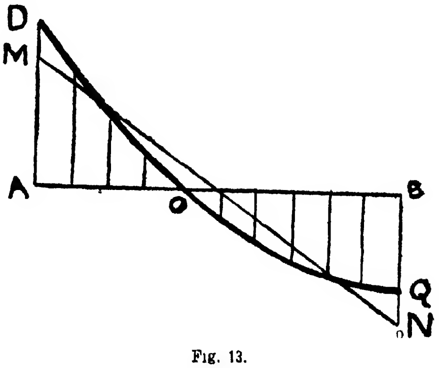


Fig. 13.

really amounts to a considerable influence in modifying the form of the line M N in Fig. 10. In this figure the amount of work that is represented by the space A O M is the same as that shown by the space B O N, and this proportion will be found to hold good in the further development of this diagram.

Effect of Connecting-rod Length.

The ratio between connecting rod and crank in Fig. 11 is as C^1 C to O C, or as 13in. to $3\frac{1}{4}$in., or as 4 to 1. At the commencement of

every stroke, or at the end of every stroke, the connecting rod C^1 C lies along a straight central line A^1 B, and at the middle of a stroke it be-

Fig. 14.

comes foreshortened by the amount of its versed sine O P. The effect of a connecting rod bearing this proportion towards the crank is to add one-fourth of the 84lb. already calculated (namely 21lb.) per square inch of piston at the commencement of a stroke, and to deduct one fourth

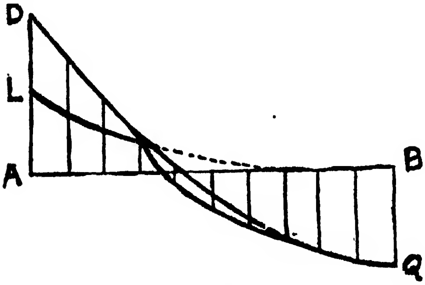


Fig. 15.

at the end of a stroke, thus compensating for the shorter or longer periods which occur with a finite connecting rod, but which are absent from one of infinite length. If the proportions of connecting rod to crank were arranged, for example, to be as 6 to 1, then it would be necessary to add and deduct no more than one-sixth of 84lb., or 14lb. only, instead of 21lb. As with the diagonal line M N, Fig. 10, so will the other following diagrams show equal areas, and represent equal powers, added or deducted, so that in the difference due to a connecting rod, there is no direct loss of power (except through friction) but only an interchange in its distribution. With the addition of 21lb. the 84lb. per square inch on the piston becomes 105lb. = A D, Fig. 12, and with the deduction of 21lb., the 84lb. per square inch becomes 63lb. per square inch equals Q B, Fig. 12. Thus Fig. 12 represents the effect of reciprocation on the forward or driving stroke, and Fig. 13 shows corresponding effects from the return stroke. Intermediate points can be ascertained by a diagram such as Fig. 16. Here the circle L N P is drawn where the radius O L represents 84lb. per square inch (not to the same scale as used with the preceding

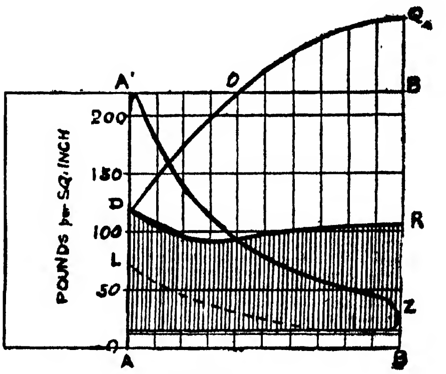
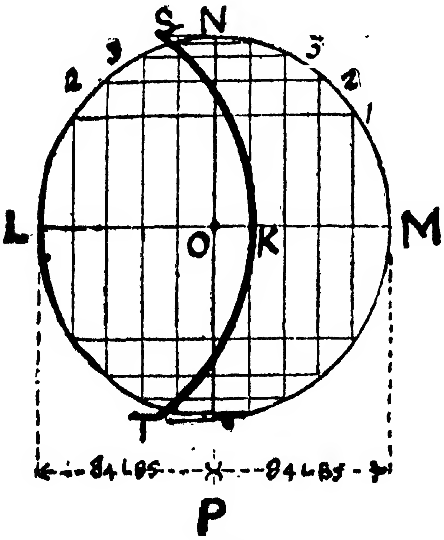


Fig. 17.



F.g. 18

diagrams). O K is marked off to the right of the centre line to the extent of 21lb., and S N and T P are drawn on two tangent lines each representing 21lb per square inch on the piston. The next thing to do is to find a centre for a circle which cuts the three points, S, K, and T, which centre, in the present case, will be found in the circumference at L. The horizontal lines L O and O M are each to be divided into as many spaces as occur with the indicator diagram, namely, five. Vertical lines from these divisions cut the circle L M N P at points marked 1, 2, 3, etc., in corresponding positions, which show the position of the crank pin over each of these ten divisions. If now horizontal measurements be taken from the points where such vertical lines cut the circle on to the vertical line N P, the intermediate distances thus ascertained may be transferred to Figs. 12, 13, and 14, thus agreeing with the conditions of an infinite connecting rod in so far as they give an exact equality between what has to be deducted from the first half of a driving stroke and added to the second half—as shown by the diagonal

line in Fig. 10 and with the light diagonal lines in Figs. 12 and 13. But if instead of measuring from points on the circle L N M P, we measure from the same points to the concave surface S K T, Fig. 16, we get the lengths of a series of ordinates which give intermediate positions where L K, Fig. 16, corresponds with A D (Figs. 12 and 13) and where K M, which corresponds with Q B (Figs. 12 and 13), and other ordinates are measured from the circle to the convex surface. Having thus ascertained the terminal lengths of these ordinates and transferred them to Figs. 12 and 13, it is only necessary to draw a curve D O Q (Figs. 12 and 13), which scales correctly the amount of pressure to be deducted from the driving pressure from A to O, or added to it from O to B, thus correcting such irregular and heavy strains as are shown to exist by the indicator diagram, and providing a new diagram which shows the pressures correctly given, and as they actually exist.

Matters relating to the compression side of the motor are illustrated by Figs. 14 and 15. The former of these figures is copied from the lower compression portion of the indicator diagram Fig. 17 (dotted) without any reference to possible modifications due to the momentum of reciprocating parts; a consideration which is recognised in Fig. 15.

Stage Pressures in the Otto Cycle.

As is well known, the Otto cycle has four stages.

Stage No. 1.—Corresponds with Fig. 12. It is the explosion of mixed air and petrol vapour, while the piston is travelling from A to B. Here the pressure of 105lb. per square inch to overcome the resistance of inertia in the moving parts is derived directly from the explosion, and at the further or B end of the stroke, a considerable pressure is available to drive and to give a very heavy impact upon the crank at the termination of a stroke at B. This power is lost.

Stage No. 2.—Corresponds with Fig. 13. It is a movement of the piston from B to A, and is the exhaust stroke of the petrol motor. Here the fly-wheel, or its equivalent, provides the necessary pressure of 63lb. per square inch of the piston for accelerating the moving parts. After passing the middle of the stroke, the power thus borrowed from its commencing half is restored, and it finally gives a pressure of 105lb. per square inch of piston when it has arrived at the termination of the second stage of its performance.

Stage No. 3.—Corresponds, for the second time, with Fig. 12. It is a movement from A to B, introducing a fresh supply of air, mixed with petrol vapour. Here again the fly-wheel is called upon to provide the 105lb. per square inch of piston necessary to overcome the inertia of the reciprocating parts, and again this power is restored during the concluding half of this stroke, giving a terminal pressure on the crank of 63lb. per square inch of piston area.

Stage No. 4.—Corresponds with a movement from B to A in Fig. 13. This is the final stage, namely, the compression stroke B to A with Nos. 2 and 4. This No. 4 depends upon the fly-wheel to provide the necessary power for giving a start to the reciprocating parts, and this power, on its return from B to A, is not fully restored, for a part of it (A L Fig. 14) serves to compress the mixed gases during the latter part of its stroke, and, instead of giving back 105lb. per square inch at the end of a stroke, the amount required for compression, as shown by A L (Fig. 14), namely, 50lb., has to be deducted from 105lb., leaving only the pressure represented by L D (Fig. 15) or 55lb. per square inch piston area, to assist the explosion by giving the use of this compression to save expending so much energy by the fly-wheel.

Effect of Fly-wheel.

All these pressures, in relation to each other and to the fly-wheel, are dynamic and quite independent of the shape or other considerations concerning the indicator diagram, or anything in connection therewith. They concern only the reciprocating parts, and the forces involved for overcoming these resistances or absorbing these pressures. Of course the whole driving power of each cylinder of a petrol motor comes originally from the explosion, and when that is insufficient to maintain the full speed it comes from the general working power of the engine, as stored up in its fly-wheel, or what may be its equivalent. Where the fly-wheel is of ample size, the normal speed is thus maintained, but it is subject to many fluctuations where, as in most petrol motors, the "fly-wheel" element is more apparent in the movement of the whole engine and whatever it drives than in the engine itself—just, in fact, as the train drawn by an ordinary locomotive engine constitutes its "fly-wheel" (and a very heavy fly-wheel, too, as it may weigh 100 tons or more and be run at 60 miles per hour).

Modification of Diagram Pressures on Crank Pin.

From the curves of pressure ascertained and shown by Figs. 12, 13, 14, and 15 it will thus be clear that considerable modifications have to be made in pressures shown by indicator diagrams for those which finally come upon the crank. In order to show the general type of these changes, an indicator diagram has been selected from an internal combustion engine, and the familiar curves will serve to investigate the whole of this interesting subject. In Fig. 17 we have an indicator diagram (AA^1Z) selected at random from an internal combustion engine (which, however, did not make 1,000 revolutions per minute) and on the upper part of this diagram is the curve D Q, with which the re-

ciprocating parts are concerned. By deducting power represented by the diagram A^1 D O, as in Fig. 12, from the first half of this stroke, for the purpose of accelerating the reciprocating parts and adding an equal power during the latter part of a stroke as represented by the space inclosed by O B^1 Q, we obtain the crooked line D R, as representing the terminations of ordinates, which, when joined together by the said curve, D R, represent the actual pressures delivered upon the crank pin, instead of the curve shown by the initial indicator diagram pressure and its expansion A^1 Z. Referring now to Fig. 17, it will be seen how heavy is the pressure, namely, B R, which comes upon the crank pin at the end of every stroke, in this case of about 100lb. per square inch of the piston area, or 2,797lb. altogether, from which pressure no relief is given. During the return, or exhaust stroke, namely, from B to A (Fig. 13), which is the second stroke of the Otto cycle, an exact equivalent to this last pressure has to be provided to restart the reciprocating parts, and such a condition of things would argue the desirability of adding some sort of air vessel, or cushion, to recover power now being lost or, rather, being expended to the engine's detriment. As air cushions are provided for parallel cases with some single-acting engines, to absorb some of this extra pressure and give it back again to assist in commencing the return stroke, there seems no reason why similar arrangements should not prove just as useful with internal combustion engines.

During the third phase of the Otto cycle the same forces are engaged as are set out in Fig. 12, but with one important difference, namely, that no extraneous power or explosion is available to start the reciprocating parts from a state of rest, or to continue the diminishing pressures required to maintain such acceleration, so all this power has now to be borrowed from the fly-wheel, or its equivalent, and given back during the latter half of this third stroke.

Then the second and third phases of the Otto cycle neither add to the power of the engine nor diminish from it, neglecting, however, those minor losses which invariably result from any changes in the type of mechanical effort employed.

The fourth, or final, stroke in the Otto cycle commences like the second (Fig. 13), by borrowing from the fly-wheel or general momentum of the whole engine, and after about the half stroke (Fig. 15) the accumulated work, instead of being returned without deduction, is partly employed compressing the mixture of air and petrol vapour, which was drawn in by the third stroke, leaving the balance of the acceleration forces to assist the first or explosion phase as far as it is available for that purpose.

Multiple Cylinder Engines.

These separate operations can easily be followed when the cycle of operations in a single-cylinder are under notice; but when the performance of one cylinder is superimposed upon that of the other or others it is difficult, if not impossible, to follow with any accuracy the chain of combined operations with this class of diagram, and therefore another type of diagram will be employed, and it will enable the necessary observations to be made with ease and an accuracy sufficient for all practical purposes.

It is now the usual practice to combine several single-acting engines to drive one crankshaft, sometimes 2, 4, and even 8 units being used, each acting in succession, according to the equi-angular setting of their several cranks. This is done according to the natural idea that as the number of engines increase so does the driving become more regular and thus more suitable for the screw propeller, for this devouring agent of power requires steady driving, since its tangential resistance is uniform all round the circle of its operations.

Where more than four distinct engines are employed to drive one crankshaft, there arises a certain overlapping of the general driving power, and where less than four engines are used there seems at places a deficiency of driving power, owing to the necessity of providing for starting the reciprocating parts. A greater or less tangential effort is thus produced, which acts to the disadvantage of the whole. In order to disentangle these and other complex variations in the driving power, it is very convenient to use an adaptation of the circular diagram of forces which has proved so useful with steam engines. By its means an observer can follow the action all round a revolution, however many engines may be engaged. This kind of diagram has not hitherto been modified to suit petrol-driven engines, or in any way arranged to suit their peculiarities.

Circular Base Line Diagram.

In order to explain the circular base line diagram system in its application to petrol engines, the diagrams 18, 19, 20, and 21 have been prepared, and in these diagrams it is assumed that the proportions of cylinders, etc., and indicator diagrams already in use for Fig. 8 are also employed with the present example, and that each engine in the sequence of its operations is the same. These diagrams show how it is possible to secure a regular, or nearly regular, tangential effort for four cylinders (or a greater number). In this present example, the cranks are set at 90° apart, two and two opposite each other, and thus securing a crude dynamical balance for the moving weights, which does not necessarily have connection with the internal pressures on the piston.

Fig. 18 represents the cycle of operations for any one of the four cylinders, and it consists mainly of a circular base line A B C D, divided by the cross lines A C and B D into four equal parts (or any other number according to the number of engines the diagram has to serve). Each quadrant of the circumference is again divided into five parts, corresponding with simi-

lar divisions on the indicator diagram, Fig. 17, and each quadrant is concerned with one stroke of the petrol engine, thus :—

From B to A relates to the impulse stroke,	Fig. 12		
" A " D " " exhaust,	" 13	For one engine.	
" D " C " " suction,	" 12		
" C " B " " compression	" 13		

The circle A B C D serves as four consecutive base lines, upon which radial ordinates can be drawn from the common centre O at the five dividing lines by which each quarter of the

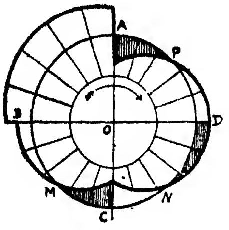


Fig. 18.

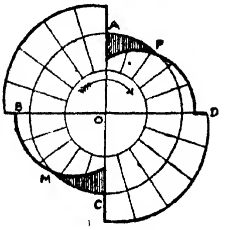


Fig. 19.

circle is divided. By transferring the lengths of the ordinates from Figs. 12 and 13 to corresponding positions on the circle Fig. 18, it is easy to add a containing line which completes the enclosures representing so much power. The shaded portions in Fig. 18 represent power given to accelerate the reciprocating masses and the plain portions represent this borrowed power returned. In the driving portion of this quadrant (from B to A) account has already been taken of these forces of reciprocation.

Whenever the Otto cycle is employed, no further power can be obtained from the engine than is given by the explosion stroke from B to A in Fig. 18, that is, one stroke out of every four; and, therefore, in single-cylinder gas engines heavy fly-wheels are required or the driving be-

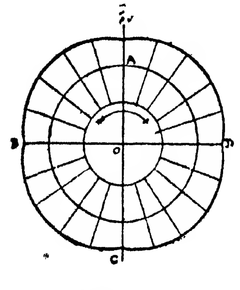


Fig. 20.

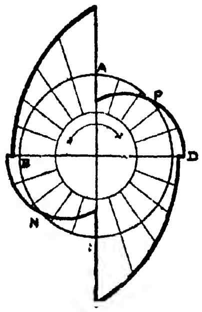


Fig. 21.

comes unsteady, irregular, and spasmodic. In motor boats, where heavy fly-wheels are inadmissible, several distinct engines are used to attain the corresponding object, namely, uniformity in driving, or some approach to it.

It will be observed in Fig. 18 that the radial ordinates from the quadrant B A are very uniform throughout the stroke; that is owing to a transference of energy shown to exist in Fig. 17 due to the action of reciprocation. This ratio, however, must not be expected to exist in every engine, for each will have its own proportion. At the point A, the first stroke comes to an end, for driving ceases altogether, and during the remaining three-quarters of a revolution power is borrowed to accelerate the movements of reciprocation and given back again to drive the engine. Thus,

Exhaust stroke.—From A to P power is given out or lent from the impulse stroke and restored from P to D.

Suction.—Correspondingly, from D to N, power is absorbed and restored between N and C.

Compression.—From C to M, power is again borrowed and restored from M to B, not so much to assist in driving the engine as in compressing the mixture of air and petrol gas which has been drawn in by the preceding stroke.

Thus, this circular form of diagram serves as a convenient system for following out the operations of the Otto cycle. It is easy to distinguish the magnitude and duration of the single force which provides all the power, and the deductions or perturbations which concern this power before it can be delivered to the main shaft to drive a screw propeller or anything else. The simple interchange of power from one part of a stroke to another, and the provision which has to be made for the assistance given to compression, will also be noticed. Indeed, this circular form of diagram is but the plain diagram with a circular base line, and constructed with equal tangential lengths measured on the circumference and not on the piston stroke.

To avoid complicating this somewhat confusing subject no notice has been taken of minor resistances, or friction, which may indeed be cancelled in practice, and, at any rate, are matters with which we are not at present concerned.

Pair of Petrol Engines with Cranks opposite.

The simplest combination for single-acting engines will be found where their cranks stand opposite one another, or where the cylinders are opposite one another, actuating the same crank. Figs. 8 and 9 are sections showing the former of these arrangements, and Fig. 19 expresses their performance. Each engine is assumed to be exactly alike as to weight, valve setting, and all other particulars, and the addition of a second engine simply does away with the second lending and returning of power which occurred during the third quarter of the previous arrangement, where there was only one engine driving the main shaft.

Here, again, B to A and D to C are impulse strokes. From A to P power is borrowed, and from P to B it is returned. Again, from C to M power is borrowed and returned from M to B.

Four-cylinder Petrol Motor with Cranks at 90 deg. to each other.

Two advantages arise from the combined action of four cylinders in a petrol-driven engine: One is that the driving is practically uniform, thus corresponding with the resistance of a screw propeller, and the other advantage is that a rough sort of dynamic balance is provided to check the vibration which comes from unbalanced moving parts.

Fig. 18 shows the sequence of operations of the single acting cylinder of a petrol-driven engine, showing only *one* quadrant—B A driving. Fig. 19 shows the combined operation of two cylinders, with their cranks opposite, showing two opposite quadrants B A and D C driving; while A D and C B are quadrants, in both of which there is a loan of power, and its restoration in the manner already described. When we come to Fig. 20, the whole cycle of operations is revealed; there each crank is set at right angles to its neighbour, and it will be noticed how very uniform the driving has become. In the present example the effect has been produced by a judicious use of heavy reciprocating parts in their relation to their modified diagram, Fig. 17. If any of these proportions are changed, corresponding effects will be produced in the diagrams throughout.

In order to emphasise the evils which might arise from heavy masses in rapid motion, the impossible diagram (Fig. 21) has been prepared and drawn to the same scale as the preceding three diagrams. But it is here (in Fig. 21) assumed that the full pressures shown on the indicator diagram, viz., A L Z are transmitted directly upon the crankshaft without any of that modification which makes the actual working diagram D L R Z to provide such smooth running effects. This comparison shows that it may not always be advantageous to lighten the reciprocating parts too much, especially in petrol-driven engines, where the variation in pressures is so great. Indeed, the necessity of designing these engines with heavy pistons for other reasons may have caused to be overlooked this important function of such heavy pistons in steadying the general action of the engine. Wherever the moving weights are improperly arranged, heavy strains are thrown on the crankshaft, and it requires some penetration to ascertain this somewhat occult cause for disaster—when such occurs.

With regard to the employment of more than four cylinders, and quite apart from the convenience of having pistons of small diameter, or with ready means of reduplication in case of accident, or from any other cause, there is an advantage which conduces to steady driving, namely, that a certain amount of overlapping occurs by the use of five or more cylinders, and thus vacant spaces may be bridged over. Each of the four cylinders can only work during half a revolution of its crank (which is reduced in the diagrams to a quadrant) and its activity has rapid changes, where one engine takes up the work of another. It may thus be a distinct advantage to have one or more additional cylinders to bridge over vacant spaces, which practical experience discovers, but which theoretical investigations do not necessarily make known.

Balancing of Revolving Weights.

The modification in four of the indicator diagrams and other matters discussed in the preceding paragraphs can be arranged so as to result in very steady driving, but it by no means follows that they are the best arrangements for balancing the rotary and reciprocating weights among themselves. To regulate this question by calculation is a matter of some considerable trouble and complexity, but as the petrol engines are comparatively small in proportion to their speed and power, they can be hung on springs and driven by electro-motors at about the speed they are intended to run, and after a considerable amount of patient adjustment they can be arranged to run without excessive vibration.

An elaborate investigation on this subject was contained in a paper read by Mr. W. E. Dally at the Institution of Naval Architects in 1901, and published in "Engineering" on April 5th, 12th, and 19th, 1901.

Horizontal versus Vertical Cylinders.

Vibration may arise from the vertical position of the cylinders in motors. When locomotives were first designed in this country the cylinders were often set vertically, the consequence of which was that an incessant chattering was set up, owing to the pistons and connecting rods offering resistance, by their inertia, to the steam pressure above them. This source of vibration was not removed until the cylinders were set horizontally, or nearly so, and this is a practice which is now universal. With vertical cylinders, the raising and lowering of the entire locomotive, or at least that part of it which was alongside of the cylinders, was a definite movement, having nothing to do with the ordinary work of the engine, but when the cylinders and pistons acted horizontally, both cylinder and piston were in horizontal movement, a little faster or slower as the piston moved forwards or backwards, a mere variation in horizontal velocity. The same class of effects may be seen in motorcars or in motor boats, so that either one or other of these may be classed with locomotives, so far as this particular matter is concerned. That this point has not been ignored or neglected is certain, for some makers have designed special engines, so that there shall be equal masses of metal, that is, pistons, etc., moving in opposite directions so as to counteract any tendency there might be to produce vibration with such a provision omitted, and this arrangement works well.

MECHANICAL HORSE-POWER.

What it is and How it is Measured.

In these days when almost all details of life, and especially that of locomotion, are controlled by mechanical means, nearly everybody is an engineer—more or less—and those of our readers who profess to have any practical acquaintance with the working of their motors may reasonably claim to be "more." Therefore it may be thought somewhat unnecessary to enter upon a disquisition upon the subject of horse-power, which is so essentially bound up with the elementary knowledge of the marine motor. But, in the first place, there will be amongst our readers many who are making their first acquaintance with motor, or other engines; and also, *because* everyone is somehow expected to know instinctively all about so elementary a subject, we are convinced that there are many with a considerable experience of motors who yet have a very hazy notion of what horse-power really means. The designer or manufacturer says that an engine of so much horse-power is necessary to secure the speed required under certain conditions, and we glibly order an engine of that power; thereafter we freely discuss speeds and powers with our fellow motorists, but, if we honestly search the depths of our knowledge, how many of us (not being trained engineers) can conscientiously say that we *know* what we are talking about? Wherefore to our subject without further excuse or preamble.

Whence the Term and What the Power.

The term "horse-power" as applied to a mechanical prime mover, i.e., a steam, water, air, or gas engine, dates back to about 1780 to 1790. In those days Matthew Boulton and Watt were making a commercial success of their steam engines, which, needless to say, were among the earliest in general use. As these engines were mostly supplied for driving mills, pumps, etc., which hitherto had been worked by horses, it became a matter of commercial convenience to rate the engines in terms of the horses they were expected to replace. Consequently Boulton and Watt set themselves to find out what was the average power of a horse in ordinary work. They took for their type the strong dray horse used in the service of the London breweries; they found that, working for eight hours a day, a horse could travel at the rate of $2\frac{1}{2}$ miles an hour, and, from experiments of lifting weights attached to a cord, led over a pulley, they also found that the average which a horse could lift steadily was 150lb. Applying these two results and assuming that their average horse would continue to lift 150lb. while travelling at its usual rate for an hour, they deduced the average power of a horse as that required to raise 150lb. through $2\frac{1}{2}$ miles in an hour, or 1lb. through 33,000ft. in the minute; or, conversely, to raise 33,000lb. through 1ft. in the same time. Thus the mechanical unit of horse-power became 33,000 foot-lbs. per minute, and, misleading as the figure is when applied in comparison with animal horse-power, it is nevertheless now universally accepted by all British engineers, and, with only slight modification to suit the system of notation of the country, by those of foreign nations also.

The Power of a Horse.

We have said that the term "horse-power" is misleading, and for the following reasons. The mechanical horse-power has an absolutely definite value incapable of variation, while the power of a horse is constantly varying between very wide limits, and varying not only with the type of horse, but also, and more important, with the conditions of the work in which its power is employed. The experiment of Boulton and Watt was no doubt a perfectly fair and reasonable one so far as it went, but, whereas the weight-lifting test lasted probably for a few minutes only at most, they assumed that the horse would continue to work steadily at the same rate for an hour, or, in fact, for a day, since their estimate of speed was based upon eight hours' work. Now we know, from other experiments which have been carried out since Watt's time, that a good strong horse in a short effort, lasting a few seconds perhaps, is the equal of as much as 15 mechanical horse-power. Also we know that a horse gets tired, and whatever his power, he cannot exert it after a certain period; in fact, it is steadily decreasing all the time until the horse is no longer able to work. On the other hand, the mechanical horse-power, while not so "forceful" as the animal at starting, maintains a constant value indefinitely. That is to say, a 2h.p. engine will continue to work at the rate of two horse-power when the two animals which it may be taken to represent are ready to drop from fatigue and are not capable of exerting anything like their full power for even a fraction of a minute. Consequently it will be realised that there can be no actual

comparison in general terms between the power of an engine and that of a horse.

While on this subject it may be well to attempt to clear up an apparent anomaly which has puzzled many people. The question arises somewhat in this form: Why is it that one horse will tow a boat, say a canal barge, at two miles an hour, while a 10-15h.p. engine is necessary to propel it at little greater speed? Well, in the first place, the pull on the tow rope is only about half the equivalent force exerted were the boat to propel itself. This has been demonstrated by experiment, and it may also be deduced scientifically.

Many years ago some experiments were carried out by the Admiralty with the object of ascertaining the difference between the pull on a tow rope and the equivalent pull (or push) when a vessel was propelling itself. Two vessels were selected, the "Active," of 3,078 tons, and the "Greyhound," of 1,157 tons, and the former was set to tow the latter. In this case the pull on the tow rope was found to be 10,770lb. The "Greyhound" was then driven at the same speed by her own engines, and the force required (deduced from indicator diagrams) was then found to be 20,830lb., or practically double as much. This was considered surprising at that time, but it really might have been expected; for consider what happens in screw propulsion. If a boat be tied up by the stern and the propeller revolved, the whole of the power is absorbed in driving a column of water astern; we all know that. If the boat be freed, and if we could hold the water still, all the power of the engine would be used in driving the boat ahead. What actually happens is something between these two, the water and the boat are driven in opposite directions, and each party requires practically the same amount of power, which of course is half what the boat's engine is providing. But, also, there are many other abstruse problems involved in self-propulsion afloat which diminish the ultimate efficiency of the engine. If the engine were able to exert its force with the same directness as the horse, that is to say by getting a firm hold of the ground and applying a direct pull or push to the boat, then a motor of the same power as the horse (not necessarily one horse-power) would serve the same purpose; but this, unfortunately, is not possible, and only a comparatively small proportion of the actual power of the engine is ultimately available to exert a direct propelling effect on the boat. Consequently it will be seen that if it be a question of getting the most out of one horse-power it would be better to put him ashore!

What is Meant by the Term.

Before proceeding further we would enjoin a clear conception of what horse-power is. It is *not* force which, however, is frequently, though hazily confounded with it.* Force may be defined as a cause which produces or tends to produce motion, and it is measured in pounds or other units of weight. It is a force (that of the exploded mixture) which causes the piston to move in the cylinder, but this force may remain constant whatever the number of revolutions of the engine, while the horse-power varies almost directly with the speed. Neither is horse-power the work done by the engine, but it is a measure of *the rate* at which work is done. Thus we have seen that one horse-power is 33,000 foot-lbs. per minute, but if the *work* of 33,000 foot-lbs. be done in half a minute then the engine which has accomplished that amount of work has been operating *at the rate* of *two* horse-power. Obviously it would not require so powerful a motor to drive a 5-ton boat over one mile in an hour as it would to drive the same craft 10 miles in the hour; but it must not be assumed that doubling the power implies doubling the speed in the case of a boat. As a matter of fact, the power required increases in proportion to the cube of the speed, more or less. Thus we see that "horse-power" is an equivalent term to "speed," while it differs from "work" in the same way that "miles per hour" differs from "miles"; also we shall now clearly understand that when we refer to a 20h.p. motor we mean a motor which is capable of doing 20 times a definite amount of work *in one minute.*

* "Power" is sometimes, though not strictly correctly, used as a synonym for "force," whence confusion results.

Nominal Horse-power.

Besides horse-power pure and simple there are several modifications of the term which have been brought into common use by the methods employed in computing or measuring the rate of work done by engines under various conditions.

It was comparatively easy for Boulton and Watt to arrive at a definite figure to represent a horse-power, but it was another matter to accurately measure the horse-power of their own engines, since the "indicator" had not then been invented. At least, they adopted a system of rating their engines by "nominal horse-power" (N.H.P.), which gave results very different from the actual horse-power. For the purpose of calculation the mean pressure (of steam) on the piston was assumed to be 7lb. per square inch, and the average speed of the piston in feet per minute was taken as 128 times the cube root of the length of stroke in feet. As steam pressures increased in course of progress the assumed mean pressure on the piston was raised by Bourne to 21lb. per sq. in., the other factors remaining as before. Since then the formula has been further amended by engine manufacturers and by the Admiralty, but as the steam engine was improved and stage expansion adopted (i.e., compound, triple, and quadruple-expansion engines) the relations between nominal and actual horse-power became still more strained, and the introduction of the engine indicator and the measurement of the mean pressure on the piston from the indicator card caused the term nominal horse-power to fall into desuetude. It is still, however, employed by

manufacturers of agricultural steam engines, but is never met with now in marine work.

Indicated Horse-power.

The modern method of rating marine (and other) steam engines is by "indicated horse-power" (I.H.P.). The indicator is mechanical contrivance consisting essentially (1) of a small spring-loaded piston whose under side is in communication with one end or other of one cylinder of the engine to be indicated, and (2) of a spring-controlled drum oscillated about its axis by means of a cord attached to some reciprocating part of that section of the engine corresponding to the cylinder under observation. The indicator piston carries a pencil which traces a line upon a paper wrapped around the drum, and the combined motions of the pencil and of the drum cause a diagram to be traced out which represents the action of the steam on the one side of the engine piston. As steam engines are double-acting the indicator has to be placed in communication with both sides of the piston, and a diagram obtained from each. To an expert this indicator card or diagram conveys much other information, but so far as indicated horse-power is concerned the sole function of the diagram is to enable the actual mean pressure on the piston to be measured—the indicator card does not give the horse-power of the engine right away. This has to be calculated in much the same way that Watt did for his nominal horse-power, only in this case the mean pressure is actually measured instead of being assumed, and instead of Watt's rule for piston speed, which assumed a constant for a given engine, the revolutions of the engine are taken at the same time as the diagram, and from the former the piston speed is exactly obtained.

The rule for finding the indicated horse-power of a steam engine is as follows :—

$$\text{I.H.P.} = \frac{2.\ \text{P.A.L.N.}}{33{,}000}$$

Where P = the mean of the mean pressures on *both* sides of piston, in *lbs.* per sq. inch.
A = area of piston in square *inches*.
L = length of stroke in *feet*.
N = number of revolutions per *minute*.

Now, if we examine this formula in detail we see that, since P is the average pressure of the steam (or of the gas in an internal combustion engine) and A is the area of the piston upon which that pressure acts, P × A is the *force* which causes the piston to move and the engine to work, and it is measured in lbs. Then L, being the length of the stroke, gives the distance through which the force acts. This is measured in feet, and the product of the force multiplied by the distance [(P × A) × L] gives the amount of work done in foot-lbs. during one stroke of the piston. A steam engine being double acting (i.e., the force being applied on each side of the piston alternately on the go and return strokes), it is necessary to double this amount to obtain the work done on the piston during a complete revolution of the engine. This amount of work will, therefore, be represented by 2 [(P × A) × L]; but in order to find the horse-power we require to know the amount of work done in *one minute*, therefore we must multiply again by the number of revolutions which the engine makes in a minute. Our formula, then, becomes 2 [(P × A) × L] × N, and if we divide this by the amount of work (33,000 foot-lbs.) which Boulton and Watt deduced, and which is now universally accepted as the equivalent of one horse-power, the result will be the number of horse-power developed by the engine.

As an aid to memory the order of the letters is sometimes transposed and the upper portion of the formula is written 2 PLAN, but the important part to remember is that the piston is measured in *inches*, while the stroke is measured in *feet*. It is also important to note that the number of revolutions a minute at which the engine is running is an essential factor in determining the horse-power; the same engine will develop *different powers at different speeds.*

Of an Internal Combustion Engine.

In the case of steam engines the speed of revolution is nearly always low as compared with that to which we are accustomed with motors, and consequently difficulties arise in applying indicators to the latter which do not occur with the former.* Special indicators are made for internal-combustion engines, and diagrams are frequently taken, but chiefly in experimental practice; it is not usual to determine the power of a motor engine either in use or (except, perhaps, in the case of the first of a type) in the factory by means of indicator diagrams. Nevertheless, when the power is so calculated the principle is the same as in the case of steam engines, and our remarks in the preceding section apply in general equally to motor engines, but with certain modifications in the formula.

All usual types of motors are single-acting (*i.e.*, they take pressure on one side of the piston only), therefore the 2 in the above formula at once comes out. In the case of two-stroke motors, in which an explosion or impulse occurs once in every revolution, that is the only modification. Four-stroke motors, however, receive an impulse once in every two revolutions only, and therefore, instead of multiplying by 2 as in the steam formula, it becomes necessary to divide by 2, so that for a four-stroke motor the formula stands—

$$\text{I.H.P.} = \frac{\frac{1}{2}\,(\text{P.A.L.N.})}{33{,}000}, \text{ or } = \frac{\text{P.A.L.N.}}{2 \times 33{,}000}$$

It is necessary to remember that this applies to one cylinder only, and that the result must

* The speed of steam turbines is greater, but the principle of their action is different, and they cannot be indicated in the same way.

be multiplied by the number of cylinders to obtain the h.p. of the motor.

This, of course, applies equally to steam engines, except in the case of cylinders arranged for stage expansion, where each must be regarded separately.

The Fallacy of Indicated Horse-power.

It will have been observed that indicated horsepower is dependent upon the pressure of steam or gas in the cyclinder; therefore the power measured is that of the piston, so to speak, not of the engine as a whole. If one takes a new motor which is fairly stiff, a considerable force will be found necessary to turn it by hand by means of the starting handle. It is conceivable that in such a motor there might be a considerable pressure of exploded gas on the piston which would be no more than sufficient to just revolve the shaft. If that motor were running, an indicator computation would show that it was developing an appreciable amount of power, which might be as much as two or three horse-power, yet one could stop the motor easily by the mere pressure of a hand on the flywheel, thus showing that, though a certain measure of horse-power may be indicated, none is available for practical purposes. In effect, a portion of the indicated horse-power of any engine is absorbed in overcoming its own internal resistances, and the amount varies considerably with different engines. Thus the I.H.P. does not give the measure of the h.p. actually being developed by the engine as a whole and available at the flywheel or clutch. Still, in the case of steam engines at least, the indicator method remains the most convenient and generally satisfactory for obtaining the horse-power.

Marine Motor Power.

Before leaving what may be styled the computing methods as distinguished from the measuring methods of finding horse-power, it will be convenient to refer to the formula of the Marine Motor Association.

For the purpose of rating boats for racing it is necessary to have some means of determining the power of the engine. The means adopted must be reasonably simple, and must involve only such factors as can easily be measured or are known beforehand. Both indicator readings and brake measurements are obviously out of the question where engines already installed in boats are concerned, and much thought has been brought to bear on this matter to devise a satisfactory method of measurement or computation of horse-power. Varying systems are employed in different countries, but the one adopted by the Marine Motor Association seems at least as simple and as satisfactory as any, though still open to criticism in certain directions. The formula is as follows :—

$$\text{M.P. (motor power)} = \frac{A \times S \times R}{C}$$

Where A = Sum of areas of pistons in square inches.
S = Length of stroke in feet.
R = Number of revolutions per minute.
C = A constant = 1,000 for four-stroke motors, and = 600 for two-stroke motors.

This formula is derived from that previously given for indicated horse-power, retaining those factors whose dimensions vary considerably, and which are known or can be ascertained for each engine, but assuming a fixed mean pressure on the piston for all engines of the same class. Four-stroke motors are assumed to have a mean pressure of 66lb. per square inch, and 55lb. per square inch is taken as the mean pressure for two-stroke motors. It should be noted that, in the M.P. formula, A is taken as the sum of the areas of all the pistons, whereas in the I.H.P. formula the area (and the I.H.P.) is calculated for each cylinder separately. The same result is, of course, obtained if the area be reckoned as for one cylinder only, and the result be multiplied by the number of cylinders.

Thus, tracing the evolution of the M.P. formula, we get for two-stroke motors (single-acting)—

$$\text{I.H.P.} = \frac{\text{P.A.L.N.}}{33{,}000} \times \text{Number of cylinders.}$$

$$\frac{55.\ \text{A.S.R.}}{33{,}000}$$

$$= \frac{\text{A.S.R.}}{600} = \text{M.P.}$$

And for four-stroke motors (also single acting)

$$\text{I.H.P.} = \frac{\frac{1}{2}\,(\text{P.A.L.N.})}{33{,}000} \times \text{No. of cylinders.}$$

$$= \frac{\frac{1}{2}\,(66.\ \text{A.S.R.})}{33{,}000}$$

$$= \frac{\text{A.S.R.}}{1{,}000} = \text{M.P.}$$

It will be noticed that the term "horse-power" is not employed, and, indeed, the formula does not pretend to give the horse-power of the engine, but only an approximation which bears a sufficiently near relation to what the actual horse-power may be expected to be, to serve the purpose of comparison in rating boats, for which it was devised. Marine power (M.P.), therefore, must not be confounded with horse-power (H.P.); they may happen to be the same in some cases, but also they may differ considerably.

It is unnecessary to enter, at the present moment, upon a disquisition on the merits or otherwise of this formula as applied to rating purposes, but obviously it has two disadvantages. The one is the method of arriving at the revolutions at which the motor attains its rated power. The other weakness of the formula lies in the value of the constant. This, as the evolution of the formula shows, is derived from the assumed mean pressure on the piston. At the

time the formula was constructed the mean pressures taken were fairly correct, but in the three or four years that have elapsed since then matters have changed in this respect, to the advantage of the four-stroke motor, whose average mean pressure has increased, and to the disadvantage of the two-stroke type, in which the average mean pressure has apparently diminished.

Judging from results of the past season, it would appear that the mean pressure of four-stroke motors should be reckoned somewhere about 70lb., giving a divisor constant of 900, while for the two-stroke motor the mean pressure should be taken at about 44lb., thus raising the constant for this type to 750. This would seem to put the two types more on an equality. But there still remains a source of uncertainty in assuming the same mean pressure for all motors of the same type. In the case of four-stroke motors, for instance, there was a case during the past season where the rating of a successful boat was challenged. On a remeasurement, the rating of the motor (and of the boat as a whole) was found to be actually less than stated, and there is no doubt the good performance of the boat was due in a large measure to the high compression and consequently high mean pressure of the engine, which caused her rated power to come out considerably less than her actual. Again, in the case of two-stroke motors, though nearly all users have been complaining that the formula rates them too high, which is tantamount to admitting that their mean pressure is not up to the assumed 55lb., yet there is a type of two-stroke marine motor where the mean pressure is 80lb. and over —more than the average of ordinary four-stroke engines! But it is hopeless to expect to get a perfect formula for the rating of power in marine motor engines unless it be possible to actually measure it, and we now pass to that part of the subject.

Brake Horse-power.

The usual method of ascertaining the horse-power of a motor engine is to actually measure it at the flywheel by means of suitable apparatus. Thus brake horse-power (B.H.P.) is that which the motor is able to transmit to the after member of the clutch (not to the propeller, for there are several other resistances interposed), and it is therefore less than the indicated horse-power of the motor. Brake horse-power is so called because the apparatus used in measuring it usually takes the form of a brake on the flywheel, though the brake may be any one of several types.

If, when a flywheel is revolving, we take a handspike or a long piece of wood and, placing one end on the floor under the wheel, pull up on the other, bringing pressure to bear on the flywheel, we can prevent the motor racing, or even bring it to a stop. If we could measure the strength of our pull we should be able to arrive at the power of the motor. That is the method of obtaining the brake horse-power in principle.

The earlier arrangement adopted with this object was called the " prony " brake. It took several forms, but perhaps the most common was as illustrated in Fig. 1.

This arrangement consists of two wooden blocks with V cuts, which are bolted round the shaft (not the flywheel in this case). Attached to the upper block is a long arm graduated in feet and inches, and to this is attached a weight. The tension on the bolts and the position of the

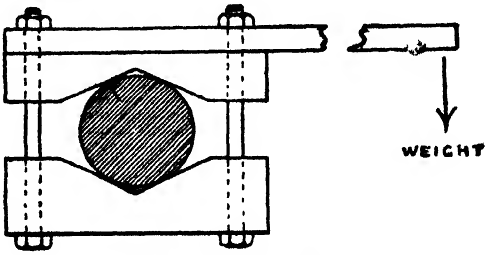


Fig. 1.—" Prony " brake.

weight are then so regulated as to maintain the brake in equilibrium. The power developed by the engine was represented by a formula employing the weight, its distance from the centre of the shaft, and the speed of revolution.

This was too jerky and unsatisfactory for anything like accurate measurements.

The Rope Brake.

The most usual form of brake adopted for measuring the horse-power developed by a motor consists in its essentials of a rope wound one turn round the flywheel, secured to the roof at one end and loaded with weights at the other, the weights being such that the rope is held sufficiently tightly round the flywheel to permit the engine to steadily maintain its proper speed under its best conditions. In practice the arrangement varies somewhat, a common method being that shown in the diagram (Fig. 2). A special flywheel or drum is usually fitted in place of or in addition to the flywheel proper, and this is made with a deeply recessed rim, in which water is run continually during the test to carry away the heat generated by the friction of the rope on the outside of the drum. The diagram (Fig. 2) illustrates a usual arrangement of this kind. The spring balance and the spokes of the drum are omitted from the side elevation (right-hand sketch) for the sake of clearness. Here the deep rim (C) is shown, and water is led into it by a rubber hose or other means from time to time, or in a small continuous stream, the water in the rim evaporating or overflowing as it gets hot. Two ropes (A, A) are wound round the drum, and are kept in place laterally by being nailed to several pieces of wood (B, B), having lips which overhang the edges of the drum. The ends of the ropes are crossed at the point

where they complete the encircling of the drum, and are secured in pairs to yoke pieces, the lower one of which (E) is attached to a hook (G) carrying weights, and the upper yoke (D) being connected to one hook of a spring balance (H) suspended from a rigid structure (K) overhead. When the brake test is in progress the ropes and drum require a certain amount of lubrication from time to time, for which purpose oil, soft soap, or tallow may be used. The direction of rotation is important, and is indicated by arrows in the diagram. There are several variations of this arrangement, but all are the same in principle. Sometimes a block and tackle is arranged to lift the weights slightly and so to ease the strain on the rope brake when it is desired to let the engine get up speed.

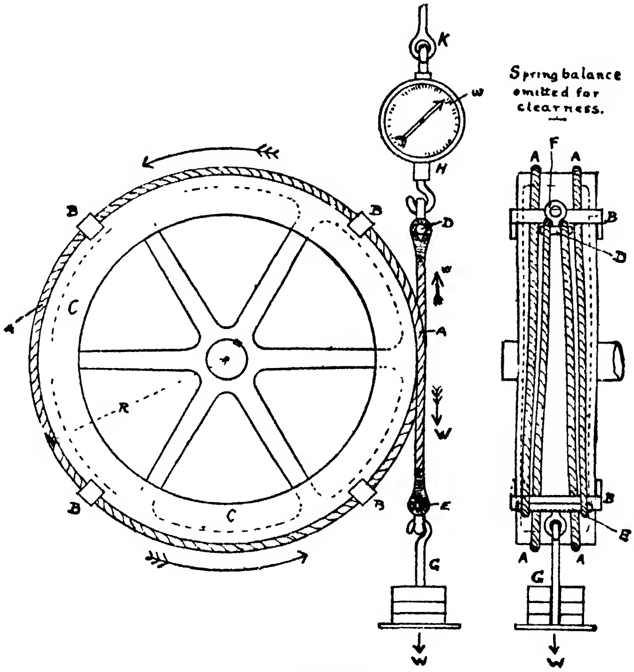


Fig. 2.—Rope brake.

In use, suitable weights are placed on the hook (G), such that the engine will run steadily at its required speed. The spring balance might be dispensed with, and the upper ends of the ropes (F) rigidly fixed if the weights could be easily adjusted to the requisite load, but as this is not practicable the balance serves to indicate the deduction from the weight on the hook to which its pull is equivalent.

The method of calculating the horse-power absorbed by the brake, which, of course, is the horse-power of the engine at the speed of revolution at which it is running, is as follows:—

$$\text{B.H.P. (brake horse power)} = \frac{(W - w)\ S \times N.}{33{,}000.}$$

Where W = weight at the hook acting downwards, in lbs.

w = pull (equivalent to a weight) at the balance acting upwards, in lbs.

N = number of revolutions a minute.

S = circumference of the circle at the middle of the rope around the drum.

$= \left(\frac{22}{7} \times 2\,R\right)$, R being the radius of the middle of rope from centre of shaft in feet.

Examining this formula in the same way as before we see that there is a force in lbs. (W-w) acting through a distance $\frac{22}{7} \times 2\,R$ in feet. The product of this force multiplied by the distance through which it acts gives the work done (or absorbed) in foot-lbs. in one revolution, and if this be again multiplied by the number of revolutions we get the amount of work done in a minute. Hence, by dividing the result by the number of foot-lbs. (33,000), representing one horse-power, we obtain the number of horse-power which the engine is developing.

The Electrical Brake Test.

The rope brake test just referred to, though fairly satisfactory and cheap in cost of plant, has the objection that it is messy and unsteady through the variation in the friction between

rope and drum; consequently the electrical method of measuring horse-power is now frequently adopted in many works of any size. The chief source of uncertainty in this case is the efficiency of the dynamo, i.e., the proportion of the mechanical power required to drive it, which it is capable of giving out again as electrical power. The efficiency of the dynamo is always known beforehand, and where a number of motors of about the same power have to be tested, it may be regarded as constant, but where the powers differ considerably within the range of the dynamo, its efficiency, since it will vary, must be known for each power at which it is used. It should be noted that the sole function of the dynamo is to convert the power of the engine into such a form that it may be conveniently absorbed, and at the same time readily measured; though, strictly speaking, in all these resistance consists of an iron trough or box filled with a solution of washing soda. A framework is erected over the box carrying an iron plate. This latter is attached by a cord to a drum, so that by turning the drum, the plate may be raised out of or lowered into the solution, thus exposing less or more surface to the liquid and imposing more or less resistance to the passage of the electric current.

The instrument board is preferably fitted with a main switch S, fuses G, voltmeter V, and ammeter H. A small controlling switch K is sometimes fitted to the voltmeter. An incandescent lamp P is also generally fitted as a rough guide to the voltage.

When a test of an engine is required to be carried out, after duly coupling up, the motor is started, and the dynamo brushes adjusted; the main switch S is then closed, and the resis-

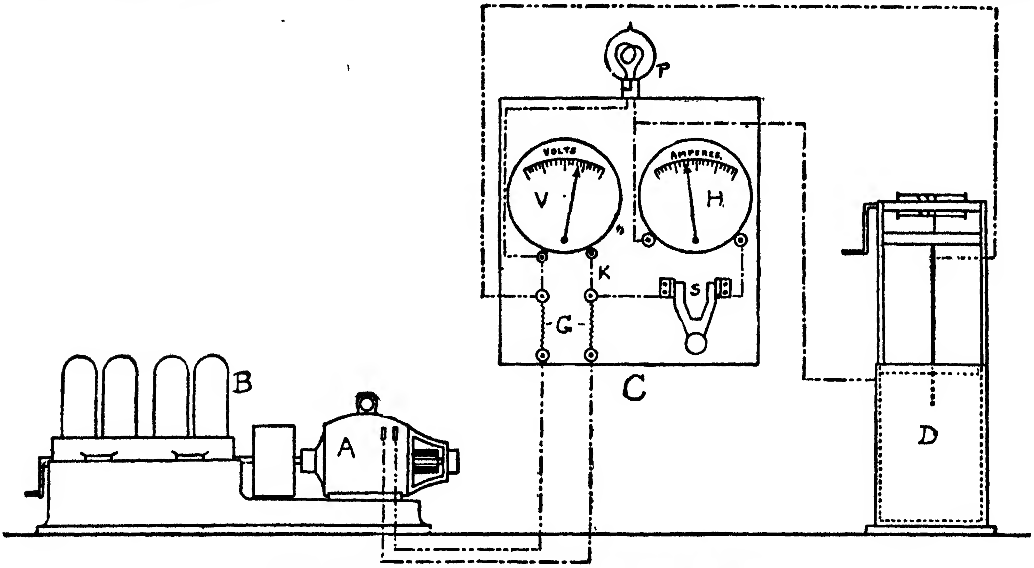


Fig. 3.—Arrangement of apparatus for electrical brake test.

brake tests, it is not the power developed by the engine, but that absorbed by the brake (or resistance) which is measured. In preparing for an electrical test, the motor is coupled to the dynamo, and the various connections are made as indicated in the sketch (Fig. 3). (This, for the sake of clearness, does not show the electrical ignition circuits of the motor, which are kept quite distinct.)

Of course, where the apparatus is used for several tests, all the electrical connections are left undisturbed, and the motor is merely lifted into place and coupled to the dynamo. In the sketch, A is the dynamo coupled to the motor B. C is the main switch and instrument board, and D is a " water resistance " which enables the load on the dynamo and consequently on the motor to be varied within wide limits. This tance D manipulated until the required current is shown by the ammeter H. A series of readings of speed, volts, and amperes is then taken and entered on a test sheet, an example of which is given overleaf (Fig. 4).

From readings of revolutions, amperes, and volts, the horse-power can now be calculated. The product of amperes multiplied by volts gives the number of " watts," which is the electrical measure of power; and, since 746 watts equal one horse-power, the result, divided by this number, will give the horse-power developed by the dynamo and absorbed by the water resistance. From previous tests of the dynamo, its efficiency will be known, and consequently the horse-power of the dynamo, divided by its efficiency (in decimal fractions of 1) will give the horse-power put into it, or that of the engine under test.

Date May 3rd, 1906. Test Sheet, No. 762.
Works Order, No. 4026.
Engine Progressive, No. A603.

ENGINE TEST SHEET.

Time.	Revolutions per Minute.	Amperes.	Volts.	Efficiency of Dynamo.	B.H.P.
H. M.					
9 00	1063	69	227	73 % or 0·73	28·7
9 05	1040	68·5	225		28·3
9 10	1082	69	230		29·1
9 15	996	69	217		27·4
9 20	1003	70	220		28·3
9 25	1017	70	220		28·3
9 30	992	70	216		27·7

Mean revs. 1026. Mean Amperes, 69 4.
Mean B.H.P., 28·3. Mean Volts, 222.

Fig. 4.—Example of electrical brake test sheet.

The formula in this case is as follows :—

$$\text{B.H.P.} = \frac{H \times V}{746 \times E}$$

where H = number of amperes.
V = number of volts.
E = efficiency of dynamo.

In practice the B.H.P. would not be worked out for each reading, but the means of all reading would be taken and the power worked out once from these means. Thus in the example taken above :

$$\text{B.H.P.} = \frac{69.4 \times 222}{746 \times 0.73} = 28.3$$

It should be noted that the number of revolutions of the engine does not enter directly into this formula; it is, however, an essential factor upon which the electrical readings depend, and is thus indirectly taken account of. It will, therefore, be seen that the horse-power recorded is that of the engine at the revolutions (or the mean revolutions) at which it was taken.

The Fan Dynamometer.

Perhaps the simplest, cleanest, and possibly also least costly method of obtaining brake horse-power is by means of the fan or absorption dynamometer. This is a simple instrument, which is capable of being affixed to the engine shaft. It consists, as will be seen from the illustration (Fig. 5), of a pair of flat plates attached to a pair of arms, which are clipped round the shaft of the motor. In the arms are series of holes (equidistant from the centre in each arm, of course), through which the bolts securing the blades are passed, and corresponding to these holes are numbers marked along the tops of the arms. Three sizes of blades are supplied, the smallest being used for powers up to 6h.p., the medium for powers between that and 30h.p., and the large blades up to 60h.p., while larger blades and arms can be made and calibrated for higher powers if required. The method of using this dynamometer is to clamp the arms to the motor spindle and, by trial, set the blades to such a distance along the arms (taking care to get both alike) as will absorb the power of the motor at the normal, or required speed of revolution. When the motor is running steadily take the revolutions by counter or other means, cube the number and multiply that by a constant corresponding to the point at which the blades are set along the arms; the result will be the brake h.p. at the revolutions recorded. The constant is taken from a table supplied by the makers of the dynamometer.

It will be noticed that, the blades being once set, only one variable (revolutions) has to be read, and the formula becomes very simple :

$$\text{B.H.P.} = N^3 \times C$$

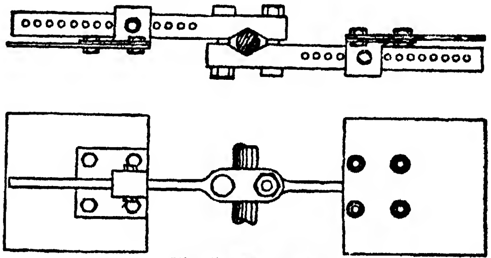


Fig. 5.—Fan brake.

Taking an instance where the medium blades were used at the 15 mark, and where the revolutions were recorded as 1,000

$$\text{B.H.P.} = 1{,}000^3 \times 0.0000000113$$
$$= 11.3$$

The blades vary in size from 6in. by 6in. to 8½in. by 17in.

It will be noted that this method of calculating the B.H.P. cannot be compared with the previous ones referred to, nor can the formula be deduced from that for I.H.P. as the others were. From that point of view it is a decided weakness of this method that one has to rely upon a constant whose derivation is unknown, and which one cannot check. But the dynamometers have been calibrated and the constants derived from a long series of carefully conducted experiments with electrical motors which themselves were checked against other brake tests, all due precautions being taken for variation of temperature, etc. The area and radius of the blades might be deduced approximately from the power required to drive fans, which varies directly as the cube of the speed within very wide limits, but each standard size of blade is independently tested for a large range of powers and speeds. While this dynamometer might not be considered satisfactory for scientific purposes it would appear to be sufficiently so for the practical purpose of obtaining the power of marine motors.

A similar type of brake has vanes working against the action of water jets instead of the air blades, and is used in a precisely similar way, also employing constants.

INSTALLATIONS FOR VARIOUS SERVICES.

Some Notes for the Guidance of those who are Contemplating Installing a Motor for the First Time.

In endeavouring briefly to advise as to the types of motor most suitable for the several classes of work for which they may be required, we must ask readers to bear in mind that it is extremely difficult, if not impossible, to lay down any hard and fast rule. Apart from general principles, particular conditions will determine what is most suitable in different cases; one may decide that a certain motor would be the best in the craft one has in view, but its installation may necessitate alterations of the vessel's arrangement which are not desirable. In that case a compromise must be effected. And, again, personal predilection is always a powerful factor in making a choice.

Therefore, it must be understood that we enunciate general principles as modified by our personal views.

River Launches.

The conditions that have to be fulfilled in a motor intended for river launches are comparatively easily met. This type of boat in general is lightly built; therefore, weight for power, the motor must be as light as possible. Also, the boat has usually a shallow draught; therefore, the propeller must be of small diameter, which means high revolution speed of the motor.

Fortunately, these two conditions fall in with one another, and are met by a motor of the automobile type. But that is not all, for vibration is a factor which cannot be ignored, least of all in a long, narrow, and lightly-constructed boat, as most river craft are. If the power be very low, such as to require but a single-cylinder motor of the four-stroke type, the vibration must be considerable, though the boat would probably be shorter in proportion to beam and depth, and, therefore, stronger and better able to withstand it, but probably a slower speed motor of the two-stroke type would be preferable.

For larger boats and powers an automobile type of engine will serve very well, remembering that four cylinders give less vibration and more flexibility than two. Such a four-cylinder motor of a good present-day make will have a range of flexibility from, say, 200 to 1,000 revolutions a minute, sufficient for all speeds that are required, but of course it must be remembered that. for use on crowded or narrow rivers, every installation should include a good friction clutch and reverse gear. For the reason that the clutch is likely to be frequently withdrawn, if only when entering locks, etc., the motor in this, more than in any other type of boat, should be provided with an efficient governor.

It will be better to have an engine rather more powerful than is required, and to run it at rather over half power, at which it will run more sweetly and with less attention. The motor in a car is very seldom needed to work up to its limit, and will probably give the best results at a considerable reduction of power, which in a boat may mean economy of fuel.

On the other hand, if the boat is so low-powered as to do most of its running at full power, the wear and tear on the engine will be increased, but in a reputable present-day motor this will not amount to very much, and is of far less importance in a river boat, which, presumably, is used intermittently and is always near home, than it would be in another class of craft.

It must be remembered that a motor of the type we are considering is designed for work in a car on the road.

Exposed pump chains, gear wheels, leaky pump, or dirty clutch will throw spots of oil in any direction, to the detriment of the general efficiency of the installation, and this is one of the legacies that the automobile engine has handed over to us.

A marine motor should not have exposed gears, chains, etc., and the pump should be so designed that it does not throw oil or water, and outside bearings should be fitted with oil-catchers, etc.

In a motorcar the engine is covered by a bonnet, and it is immaterial how much dirt is thrown about or how many exposed gears or chains there are, so no attention has been paid to this matter.

To a great extent this is obviated in a boat by placing the motor over a metal tray and completely housing it in; but prevention is better than cure, and, even if you prefer a motor-cover, it is better to be always sure you have a clean motor inside than to know that the interior of the case will not bear inspection from any cleanly-disposed person.

The modern method of installing a car engine in a launch is to provide an instrument-board similar to the dashboard of a motorcar, and on it to mount all the controls, lubricators, commutator, etc., and to also arrange the board so that the flywheel and clutch can be protected by a neat brass cover attached to the board, and to so arrange the reverse gear lever, clutch, controls, steering gear, etc., that the navigator of the boat may have everything within his reach, and have complete control of the machinery and boat without altering his position.

It is very desirable on such a river as the Thames, where locks and traffic have to be negotiated, to have an engine that will start by turning on the switch, and for this reason, where magneto ignition is fitted, it would be a great convenience to have high tension ignition as well: unless such an arrangement as the Bosch or Simms self-starting attachments be fitted; but in this case we are dealing with a compromise, a substitute for the engine designed expressly for marine work, and as car engines are usually designed for easy starting, there should be little difficulty under this head.

It must be borne in mind that, whatever arrangement the maker of this motorcar engine has provided for the exhaust, when it is installed in your launch it must be water-cooled, and this must be taken as an indispensable condition.

Beach Boats.

By this term we mean open or partially decked boats which are generally kept on and used from the beach. They may be private boats for fishing or pleasure purposes, or they may belong to that rapidly-increasing class which is let out on hire. The conditions are almost similar in both cases.

Such boats will be comparatively small, stoutly built, and with a keel, since, in most cases, they will need to be hauled up the beach; in any case, they must be able to safely take the ground. The speed required will not be great, therefore high power will not be necessary. The propeller will need to be fairly small, since it must not project below the keel, but as the boat will have a greater draught and coarser lines than the river craft, so small an area will not be desirable, consequently the speed of the engine should not be so great.

As the boat and the motor will be exposed to the weather and salt spray, all moving parts must be properly enclosed, which, however, does not mean a mere box over the engine.

The automobile type of engine will not be satisfactory in this case, but a properly designed marine motor must be installed, though, as it will probably be small in size and fairly easily removable from the boat, it is not necessary that there should be provision for adjustment of internal parts beyond the valves, etc. Aluminium should not be employed for sea work.

Regarding the case of the hiring-out or trip boat; economy of installation is an important point, therefore, vibration being of secondary moment, a single-cylinder motor may be used, though two cylinders would be better. Although petrol is more expensive than paraffin, an oil motor requiring a blow lamp for starting or running is not suitable for this work. A two-stroke motor would possibly be the better type for this class of work, on account of its freedom from valves and gear, and its general simplicity, but provision should be made to prevent reversal when starting in the hands of an inexpert person. Unprotected iron or steel parts should be avoided as far as possible, and where used should be adequately covered against rain or spray. This applies to bolts and nuts, particularly in the smaller sizes. All parts requiring attention must be readily accessible, but as there will be a number of people in the boat, the whole installation must be properly encased or otherwise protected from damage. The circulating water inlet must be in such a position that it will not be damaged by grounding, and that it will not be liable to be choked by weeds, nor take in sand stirred up by the keel. Also it is advisable to provide arrangements for clearing the inlet of obstructions from inside the boat. This is desirable in all types of boat, but particularly so in a beach boat. The circulating water discharge must be above the water line, and in such position that it can be easily seen.

Magneto ignition should be fitted, preferably low tension. Accumulators and high-tension coil may be fitted for starting or as stand-by if desired, but, if fitted, battery, wiring, and terminals must be thoroughly protected, as well from accidental damage as from wet.

The starting handle in such a boat should be of the flywheel disappearing type or else removable.

An adequate bilge pump is a necessity; it is a convenience to have it driven off the motor, but in any case a hand pump should also be provided.

The control arrangements must be so arranged that the boat is always under complete command of one man, and the several fittings must be so installed that their setting cannot be deranged by persons accidentally knocking against them.

Yachts' Tenders.

The requirements in this case, though they may vary with the different classes of boat, are in many respects very similar to those in the case of beach boats just referred to. The smaller classes of yacht's boat, at least, may frequently be required to land on a beach, and the arrangements must, therefore, be made with this in view.

For a dinghy or small launch of fairly low power a two-stroke motor, in conjunction with a reversible propeller, is a very suitable outfit, and, provided it be in careful hands, such a motor need not require an engine case. Needless to say, all ignition gear, etc., should be provided with protecting covers, easily detachable.

In a small boat, where space is of importance,

and with a two-stroke motor, which can be started with a turn of the flywheel; a clutch is not essential, though always a convenience.

In a launch attached to a smart yacht, perhaps more than in any other class of open craft, dirt and oil cannot be tolerated; therefore, unprotected chains and gear wheels must be avoided. There is no reason why oil should be thrown about at all by a properly-designed marine motor, but proper guards and trays, with adequate provision for keeping the latter clear, will entirely prevent annoyance from this cause.

A 16ft. dinghy with a two-cylinder two-stroke motor of about 4h.p. might be expected to weigh in the neighbourhood of 8cwt., and would, therefore, easily sling in davits of a fairly small yacht. The price would be about £150, according to finish and fittings, and the speed about eight miles an hour with five or six passengers.

If greater accommodation and speed be required, of course a more powerful motor must be installed in a larger boat.

In this case it would be better to fit a three or four-cylinder four-stroke engine of a good marine type, having a normal revolution speed of not more than 800 per minute. In a 20ft. or 25ft. launch, where there is more available space, and in view of the fact that this type of motor does not so well adapt itself as the two-stroke to neat and compact construction, the motor should be housed in a protecting case, the top and all the panels of which should be removable. Reversing propeller or reversing gear may be fitted, but with a friction clutch in addition in either case. If the launch be required for towing purposes, a solid three-bladed propeller and reverse gear would be preferable.

Many of the remarks in respect of beach boats concerning the sundry items of installation apply equally in the case of yachts' launches and all other sea boats, and that section should be read in conjunction with this.

Of course the size and type of yacht's launch will vary very greatly according to the tonnage of the vessel to which she is attached and the special requirements and fancies of the owner.

A 25ft. launch with a beam of 5ft. 6in., and a 25 brake horse-power engine at, say 600 or 700 revolutions per minute, will give a sustained speed of 11-12 knots, and this question of sustained speed must not be lost sight of, for it is quite different in value from the maximum speed that sometimes can be attained for a short time with skilful attention, with the gear and ship in A1 condition.

The boat will lift at something less than a ton, and it will be found that such a boat will tow a 100-ton yacht.

Cabin Cruisers.

In selecting a motor installation for a sea-going cabin boat other considerations have to be taken into account.

In the first place, it has to be remembered that one may have to live, if not in the same cabin as the motor, at least next door and under the same deck.

One of the first questions that will arise is in respect of the fuel to be used—petrol or paraffin—and concerning which opinions still differ. The objections may be summed up in saying that petrol is unsafe and that paraffin is smelly and all-pervading. The root of the matter, however, is the same in both cases—faulty installation. Petrol is perfectly safe if kept within bounds. If the installation of tanks, pipes, and joints is as it should be, the only leak can occur at the carburetter. There *should be* practically none there, but proper precautions for catching any overflow and draining or pumping it overboard (not into the engine tray) will obviate any risk from that quarter.

The same applies to paraffin; there should be no leak anywhere except, *possibly*, at the vaporiser.

Still, there may be the risk of damage to tanks or piping where not adequately protected, and there will, consequently, always remain a prejudice against petrol in a purely motor cabin boat. Also, there is the matter of expense of fuel. Therefore, we will assume a paraffin motor is likely to be fitted.

Now it is highly important that the engine should be able to use any commercial petroleum, from Tea Rose or Silver Spray to White Rose or Shale oil, but do not think of using crude or residue oil, as the latter can be best described as "unclean." An engine that requires some special brand of oil will be a nuisance, for the shipyard or ship-chandler you knock up on Sunday morning will most likely not have heard of such a brand.

As for the engine itself, weight is not of paramount importance; 50lb. per brake horse-power can be considered as satisfactory, but pure increase of weight does not always mean increase of general strength. The factors, which while increasing weight yet increase the stability and wearing qualities at a greater ratio, are increase of bearing surface through larger crankshaft, gudgeon pin, etc., through bolts and stays to take strains reacting from the piston, flanged joints for pipes, substantial levers and hand motion to withstand rough usage.

Those factors which simply increase weight with no corresponding advantage are, heavy piston and connecting rods requiring heavy balance weight, and greater strength of frame to withstand the inertia effect, thick water jacket and other "non-combatant" parts, through a desire to substitute cast iron, which is cheap, for accurate moulding and machining, which are dear, and extra thickness of metal in the frame owing to incorrect design. It must always be remembered that lightness of reciprocating parts means a relief of strain on the engine, and therefore piston, connecting rod, and crankshaft must be of good design and material, so that inertia of the moving parts is reduced as much as possible.

A fairly heavy flywheel is desirable, as it tends

to steady running with a varying immersion of the propeller in a seaway, and so reduces vibration and noise.

Next to weight comes bulk, and in a ship bulk must be measured by overall dimensions.

When the motor is installed make an imaginary rectangular box that will just fit over the engine with all the fittings, and the inside dimensions are the dimensions of the engine.

In a cabin boat, however, it is, of course, not necessary, nor even desirable, to fit a case over the motor.

The engine should be snug, the lower part free from all appurtenances, and preferably it should not have any delicate part of its mechanism below the floor level, or even in line with it, for such appliances are out of sight when under the floor and are neglected, and if they are on the floor line every spanner or other object that carries away will fetch up against your magneto, carburetter, or whatever it may be.

In a small craft one is apt to jostle the engine, so to speak, and the fewer delicate accessories that are about the better for all concerned. To come below in bad weather with wet clothing and to be rolled against a sparking plug is bad for both, and a little care and forethought on the part of the designer will obviate this.

In an open boat which seldom goes far from home the motor can easily be removed for any major repairs or adjustments that may be necessary, but in a cruiser the case is quite otherwise. The motor is larger and heavier and is installed in a cabin; therefore it is very desirable that provision should be made for carrying out all but the most serious adjustments and repairs in place. This means a really accessible motor, with ample inspection doors, etc., but it also means—a matter that is frequently overlooked—so installing the motor in the vessel that it can be got at.

A reversing gear, with good clutch, and a three-bladed solid propeller are most suitable in this case.

High-tension ignition cannot be recommended for this class of work, on account of the difficulty of recharging accumulators on a cruise, unless a dynamo driven off the engine be fitted.

Auxiliary Motor Yachts.

Much the same conditions apply in the case of the auxiliary yacht as in the cabin launch, but with this difference. In the latter adequate provision is made for the machinery, while in the auxiliary the motor is frequently regarded as of very secondary importance, and is relegated to a position which is comparatively unfavourable. At the same time, a much smaller motor is usually employed, and, though it be stowed where it is difficult to work at, it can generally be lifted out bodily if necessary. This, of course, applies to comparatively small craft; larger vessels would be designed with a proper engine-room, and it is the former we are dealing with at present.

The type of engine may be four-stroke or two-stroke, though, seeing that the "motorman" is often the yacht's boy, the latter might be preferable. The propeller must be two-bladed, and visible marks must be made on the flywheel to enable the propeller to be placed in the vertical position behind the deadwood for sailing. A reversible type will be preferable, and with feathering blades for choice. A good clutch must be provided, and this, as well as all control of the motor, must be so placed that they may be easily operated by the helmsman, ensuring complete control of the vessel.

It is not always realised how important it is in this class of work to have satisfactory controlling devices. If the controls are on deck, the person controlling the engine should be able to slow down or go astern without having to nurse the engine, so to speak. In fact, the engine should be able to take care of herself, whatever is done on deck.

In larger vessels, where a proper engine-room is provided, adequate telegraph arrangements must be installed—*and kept in order*. Never trust to a voice-pipe anywhere for the issue of instructions upon which the safety of your own or another vessel depends.

Utility Craft.

The requirements and suitable installations for commercial vessels generally are dealt with elsewhere in this book, therefore it is not necessary to go into the matter here. It may be remarked, however, that the type and size of motor to be used and its method of installation will be based largely on particular circumstances in each case. In general it may be said that weight and space in a money-earning craft are of less importance than economy of fuel consumption and freedom from risk of breakdown. As the wages account is frequently far more than the expense of fuel and oil, it is important, so far as may be practicable, to arrange for the motor to be controlled from the helmsman's position. Mechanics are generally expensive, and, in other spheres than their own, frequently unhandy luxuries, therefore the motor should be as simple as possible and capable of being taken care of by a deck hand.

In public passenger boats, including ferry boats, the motor should be so placed and protected that it cannot be interfered with by the passengers.

In all craft where regularity of service is of the utmost importance, and in all sea-going craft, twin screws, driven by separate engines, are very desirable, since a mishap to one will not incapacitate the vessel.

HINTS ON INSTALLATION.

Next in importance to the correct and most efficient construction of the motor-boat hull, and the most desirable neatness of her lines, comes the installation of her power system : the relative balance of this and the general arrangement of the boat is of very great importance if the vessel is to do all her designers estimate for her. The installation of the prime mover and its dependants is often perfunctorily carried out, and as the smooth running of the engine so largely depends upon it, it is well to give special attention to the details emphasized herein, when we hope the results will more than repay the extra care.

In too many instances the motor manufacturer has provided the boat-builder with the drawings of the motor he is designing, but before the engine is finished alterations are made which vitally affect the builder's arrangements. Then, too, the maker of the motor, unless he be a practical boating man, is apt to overlook the accessories and details, provision for which has to be made after the construction is completed, and he is in such cases surprised that the hull cannot be altered to suit the machinery.

For our present purpose we may divide boats roughly into two classes : those constructed with a slipper stern (Fig. 1), and those with a keel or deadwood stern (Fig. 8).

Tail-shaft and Stern Tube.

To consider the slipper stern class first. Assuming that a drawing is obtainable showing the section of the boat, this should be carefully compared with the boat to see that the main dimensions are correct, such as width between bearers, position of floors, depth of frames, etc. It will be noted that two stations are marked, one forward at A, which should be at a distance (C) from the inside of stem. The vertical height (H) at A is measured from the top of the hog piece; a small batten should be screwed across the top of engine bearers at this point, and a ⅜in. hole drilled through exactly central between engine bearers, and at a height equal to H + ⅛in. This height is increased by the ⅛in. to ensure the engine, clutch, etc., not being too low, as the tendency is always to work down; for in all wooden boats it will be found that there is a slight sinking of engine, and unless it be carried on long angle irons and the weight well distributed it will be safe to leave the engine a little high.

A small tin or steel plate with a 1-16-in. hole in it is then secured over the ⅜in. hole, so that the exact centre may be adjusted correctly and a fine piece of strong twine or steel wire put through and secured. The point (D) must now be sought on the drawing, and if the other dimensions have proved correct, as shown thereon, a small slot may be cut in the hog piece at this point, so that the wire may be pulled through and secured at the correct position (B) outside without touching the hole.

This position is measured vertically downwards from the outside of the skin of boat, and in a fore-and-aft direction (E) from extreme after end of boat.

A wood bracket or piece of bent iron, or a combination of the two, is then secured to the boat to carry the end of the line (G) (Figs. 1 and 2).

The propeller (or skeg) bracket (K) must then be shored up from the floor at the position shown on the drawing (Fig. 1), and the line carried through it, passed through the small hole in the bracket and made fast.

The line now occupies a position which will be exactly central through engine, clutch, shafting, etc., and the various positions to be occupied by flywheel, under part of clutch-case, engine-case, and couplings should be checked to make sure that there is sufficient clearance, bearing in mind

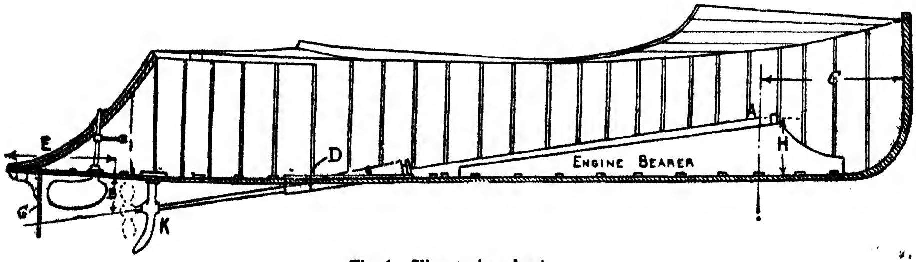


Fig. 1.--Slipper stern boat.

that a copper tray will be fitted under the engine, and the flywheel should be at least 1in. clear of it if possible, as otherwise a small quantity of water in the tray will touch it and be thrown all over the engine. It may be found necessary to pack the skeg (K) away from the boat to

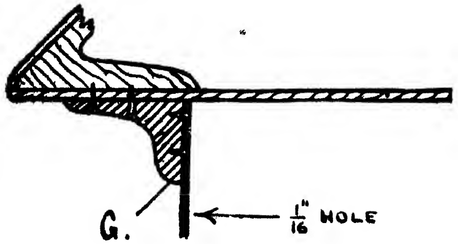


Fig. 2.

make the centre agree with dimension (B). If it can be done by setting the arms slightly, or by shifting it fore and aft, it will be better, providing that in the latter case the distance between propeller boss and bearing is not too great. This distance should be about ½in. If there is a great distance here, it will tend to increase vibration.

If the bracket must be packed away, a neat wood chock cut exactly to the thickness must be placed under each foot and made tight with a jointing of equal parts of red and white lead, countersunk bolts being put in from *outside* and pulled up tight *inside* on washers or a plate, it being usual to fit a strong chock of wood to receive them.

The line may now be withdrawn and the stern tube fitted. The stern tube usually adopted for

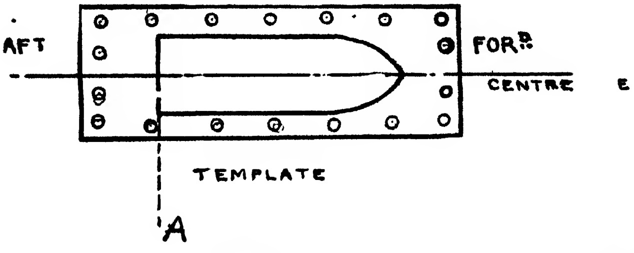


Fig. 3.

Fig. 4.

this class of boat is shown in Fig. 4. It will be necessary to cut a template to fit over the under side, which will be shaped somewhat as Fig. 3, the line (A) will correspond with the outer end of the stern tube, and, if the template be laid on the hog so that A is on the point arranged for the after end of tube to occupy, a line may be scrieved round and a hole carefully cut out so that the tube beds down into it. Four bolts may now be inserted and the stern tube pulled down into position and the line stretched again, this time through the tube. The distance must now be very carefully measured with a pair of inside callipers from the line to the inside of the tube at each end, and from the line to the inside of the skeg bracket hole, and the tube and bracket adjusted till the line lies dead true and central in tube and bracket. When this is satisfactory the remainder of the holes in the tube flange may be drilled and the stern tube bolted down finally in position, making a watertight joint with red and white lead. The propeller shaft, or tail-shaft as it is also called, can now be inserted, and if the foregoing operations have been well done, it may be easily spun round when in its proper position. The propeller is to be slipped on and nutted hand tight and the shaft pushed up till propeller boss is at the proper distance from the bracket.

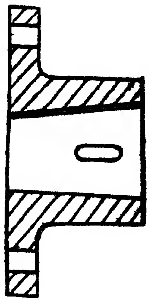


Fig. 5.

It may be well to mention here that if the shafting is to be removed from inside the boat an intermediate length must be fitted between the clutch and propeller shaft, so that the latter can be removed without lifting the clutch.

The omission of this precaution frequently leads to vexation and expense at a future date. In any case well-fitted loose couplings are an advantage; they should be fitted with a feather or sunk key, and a cotter, as in sketch (Fig. 5), and a very good job may be made by grinding them on with emery flour and water.

If the tail-shaft is fitted with such a coupling, it can be withdrawn without disturbing any of the machinery. So much for the stern tube and propeller shaft.

Engine and Clutch, etc.

We are now ready to instal the clutch and engine. Many makers now adopt an excellent practice of bolting their engine and reversing gear to stiff angle irons; this simplifies lining up in the boat, as the clutch and engine being already lined up, all that is necessary is to line the after coupling of the clutch to the forward coupling of propeller or intermediate shaft.

This is done by dropping the clutch (or clutch

and engine if so fitted) on to the bearers so that the two faces of before-mentioned couplings are about $\frac{1}{4}$in. apart all round their circumference.

In order to do this it will probably be necessary to plane or adze down the engine bearers so as to let the angle irons down till the coupling faces

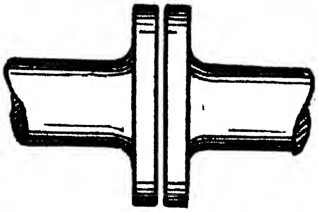


Fig. 6.

are true. They may then be brought close together (Fig. 6) and tested with a feeler gauge or steel rule. When they are at an equal distance apart all round, as felt by this gauge, and remain so when the shaft is rotated by hand, the angle irons may be securely fastened to the wood bearers by coach or ordinary countersunk wood screws.

If, however, the clutch and engine are separ-

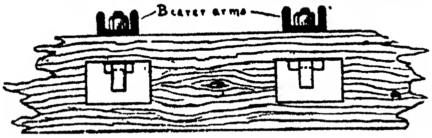


Fig. 7.

ate, it will be necessary for the bearers to be about $\frac{3}{8}$in. lower than the bracket arms of the clutch and engine, this difference being made up with packing pieces of brass or hard wood.

If a cheap job is desired, it will be enough to secure the engine and clutch as in Fig. 7, but a much better plan is to have a rough pattern made and cast some plates as Fig. 9. These may be either with a single boss as shown or with two or more of same centres as engine and clutch bolt holes.

Stern Tube of Keel or Deadwood Stern Boats.

The procedure in keel or deadwood stern boats is as follows :—Referring to the builders' drawing (Fig. 8). At the after or outer end of the boat the transom is produced vertically downwards to meet the line of keel, and a height of centre (C) is marked off on this line.

A batten should be secured across the engine

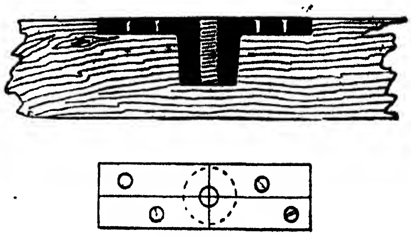


Fig. 9.

bearers at forward end (Fig. 10), as before described, to which one end of the line is attached. If there is no hole already in the deadwood, the position of shaft centre must be marked off on it

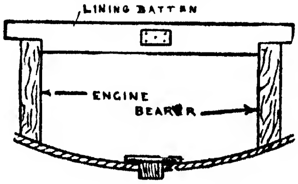


Fig. 10.

from the drawing, and a hole put through with an auger, taking care to bore it true with the centre line. This may be more easily accomplished by boring from each side of deadwood, when, if the holes do not meet quite fair, they may be opened out true with a boring bar. Having now got a hole right through, the line may be stretched through it and through a hole in a batten nailed to the transom, unless the boat is built with a permanent rudder post, when the line may be secured to that. It must be noted that when pulled taut the line passes through the hole without touching anywhere, and its distance from the bottom of the boat frames is checked by the

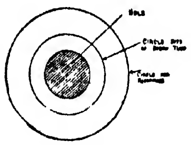


Fig. 11.

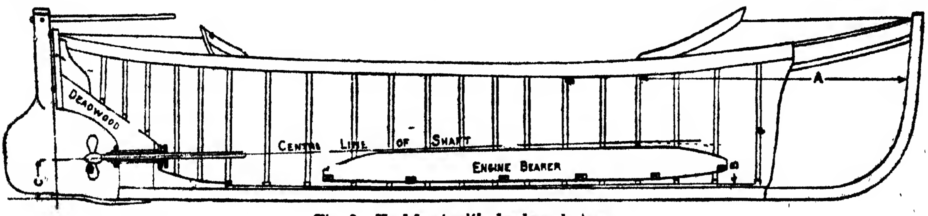


Fig. 8.—Keel boat with deadwood stern.

drawing, to see that there is ample clearance for flywheel, coupling, engine casing, etc., and that there is sufficient room under the counter for the propeller to clear freely. If all is correct, two

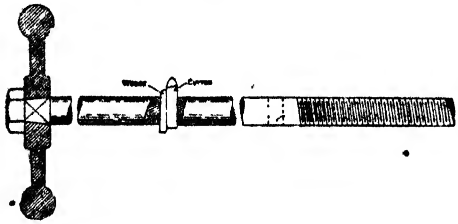


Fig. 12.

circles (Fig. 11) should be drawn on the outside of the deadwood, one the exact size of stern tube, the other for reference when boring the hole. The line can now be withdrawn and the

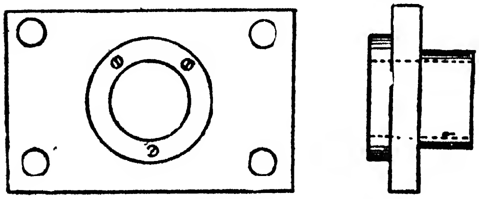


Fig. 13.

boring bar (Fig. 12) inserted. This is a bar of mild steel of about 1in. diameter and 8ft. or 10ft. long, according to length of dead-

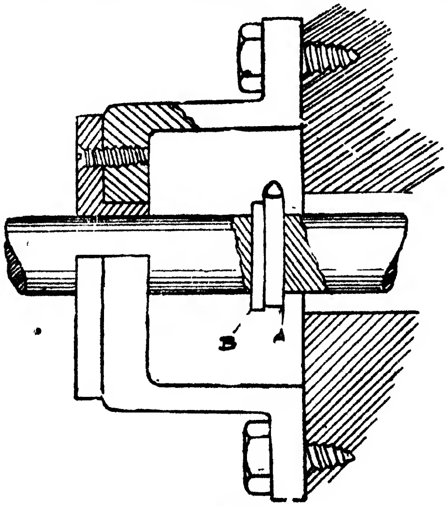
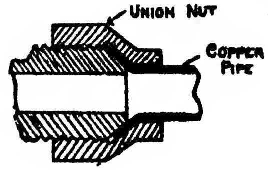


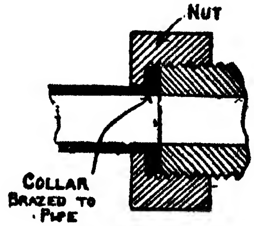
Fig. 14.

wood. It is screwed at one end for about 3ft., at 10 or 12 threads per inch. This end runs in a suitable nut (Fig. 13) carried on a plate, which is screwed to a stout temporary batten, the other end being carried in a bracket (Fig. 14) secured to the stern-post. At intervals of about 8in. are slotted holes, and into a convenient one of these is inserted a cutter (A) and wedge (B), the space in bracket allowing of this being easily adjusted. It will now be seen that on the wheel handle being rotated the cutter will gradually traverse the deadwood, boring out a clean hole parallel to centre of bar. This is repeated until the hole is large enough for the stern tube to be tapped home with a wooden or lead hammer. The line is then again stretched through, and if everything has been carefully carried out it will be found to be exactly in the centre of the tube at each end. The shaft may now be pushed in and propeller nutted on, and the desired clearance allowed between boss and stern tube. The clutch and engine may then be dropped in and lined up as already described in treating of slipper stern boats.



CONED JOINT.

Fig. 15.



FACED JOINT

Fig. 16.

Piping and Water Circulation.

The holes in the boat's skin may now be marked off and fittings inserted and wire templates taken off for copper pipes.

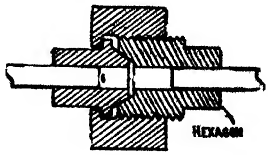


Fig. 17.

The joints for these are most easily made by belling out the ends and having the union nuts coned as in Fig. 15; another and better method is to braze a ring on to the end of the

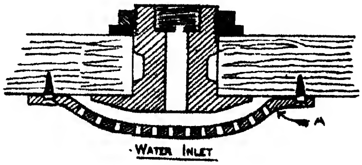


Fig. 18.

pipe, as in Fig. 16. The pipe union joint adopted in Admiralty practice is shown in Fig. 17.

In small boats it is hardly necessary to fit a sea-cock on the circulating water inlet, but if a

fitting similar to Fig. 18 is used, one of the union joints or a suitable cock may be screwed into it. In either case a strainer plate should be fitted over the hole to keep weeds or refuse from choking it up. This may be a thin copper or brass sheet disc belled out in the middle to at least ¾in. The same fitting as inlet may be used for outlet overboard. It is usual to fit the

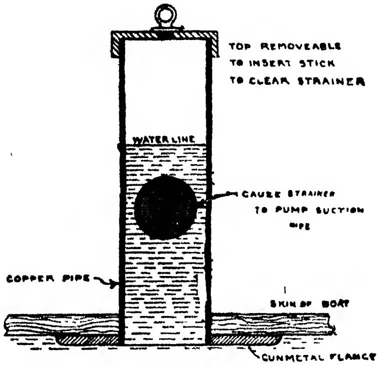


Fig. 18.

inlet nearly on the bottom of small boats and the outlet about 3in. above the water-line; the discharge water can then be readily seen and its temperature felt by the hand.

Another method of fitting the circulating inlet is to fit a copper or galvanised iron tube right through the bottom of the boat (Fig. 19) carried up to sufficient height above water-line to prevent shipping any water when the boat is roll-

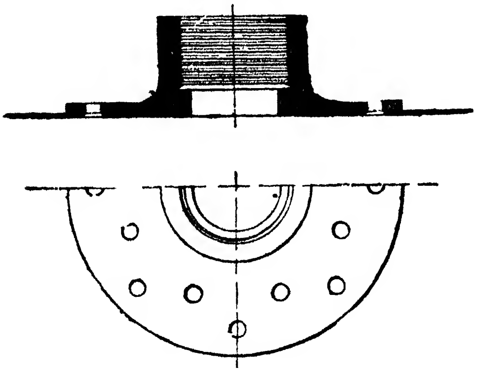


Fig. 20.

ing. To further ensure this a cap is fitted to the top of the tube. A stiffening plate is riveted into the tube, into which is screwed the connection to suction pipe of pump; and over this hole on the inside of the tube is fixed a perforated strainer plate. It will, therefore, be seen that if any weeds, etc., got in and choked this guard, they would be easily poked away with a stick from the top. Another arrangement is illustrated on page 157.

In steel boats the circulating inlet is riveted to the hull, the joint being made with red lead paint. It will be noted (Fig. 20) that it has a spigot turned on it, which should be just the thickness of the hull plating. It is shown screwed internally for a cock; but may be screwed outside or a short piece of pipe or bend used instead as circumstances require.

For all sea-going boats it is advisable to fit a bilge pump; if a large boat, it should be arranged to drive from the engine, but a hand pump is all that is necessary in small ones. The suction pipe should be carried to the lowest part of bilge and the end either closed up and saw cut or carried into a strainer box of gauze wire or perforated plate. The delivery pipe should be carried through the boat's side, somewhere very near the water-line; the dirty water from the bilge will not then trickle down and leave a dirty mark.

General.

It is essential that the wood engine bearers should be carried well fore and aft, to ensure the weight and work being well distributed over the boat. This is particularly necessary in slight racing boats, and in all cases it will minimise vibration. The engine bearers should be secured by copper bolts right through the planking and with the ends well riveted over. Two or three knees should be fitted outside the bearers and the two well tied together in two or three places under the engine, as may be convenient.

In the case of steel boats the bearers are made continuous fore and aft, worked into the hull, and secured by angle irons where passing through bulkheads; and also well tied together by intercostals.

Fuel Tank.

This should be made of not less than 16 gauge copper, the seams and ends being tinned and riveted—pitch of rivets about ¾in. In large sizes internal stays and wash plates must be fitted, having large flanged palms sweated, not riveted, to the inside of the shell, so that, in the event of the side collapsing, there will be no

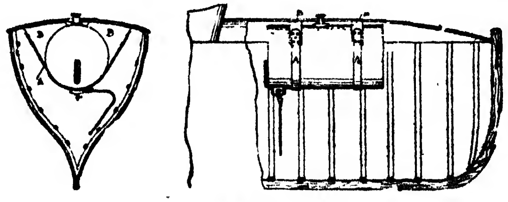


Fig. 21.

leakage at strained rivets. The strongest shape for a tank is round, the next best is oval, and this form has the advantage of depth, when fitted under the deck forward, for gravity feed.

A tank fitted in this position must be secured to the turtle deck (Fig. 21) by straps (A) and wood chocks (B) cut to fit closely to the tank.

In this case the bottom of the tank should be at least 9in. above the level of the carburetter, and more if possible, for if the boat is down by the head and the supply of petrol is low in the tank it will not run down to the carburetter.

It is very important that the tank should be strongly secured, that it may not work or break

This is the sump or drain, and serves as a collector for any water in the petrol, which may be drawn off from time to time by a drain cock in the bottom (D).

EE are two facings about ¼in. thick, and are tapped to receive the petrol supply cock (C) if gravity feed is employed. An illustration of a type of spring-backed plug cock is given in Fig. 23, and another form of fuel tank drain is shown in Fig. 38.

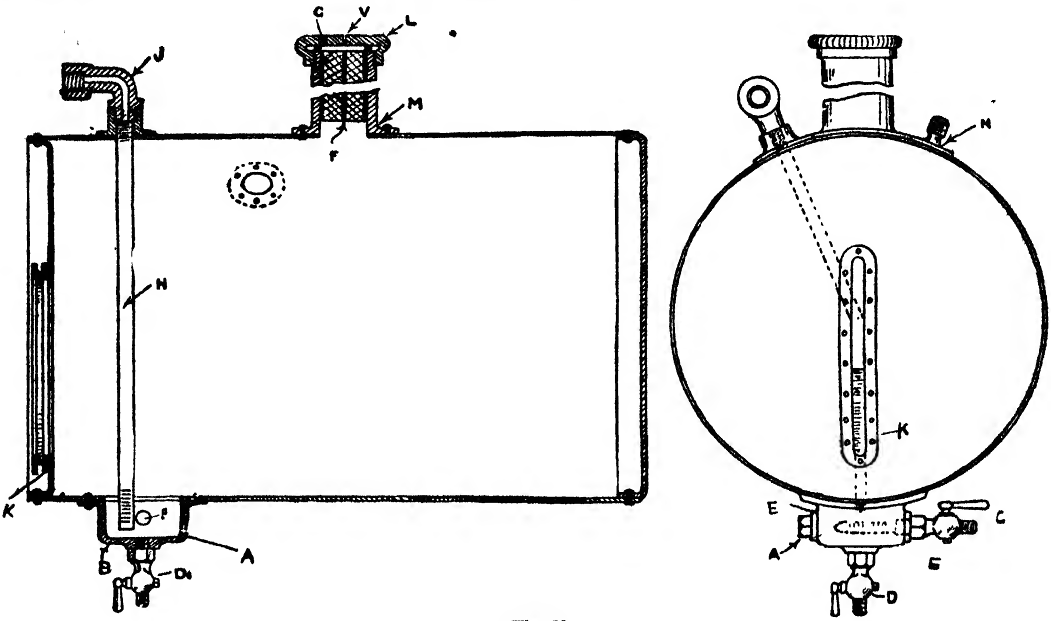


Fig. 22.

loose when the boat is pitching in a seaway, a sure cause of leaky joints and broken connections. The only objection to the forward posi-

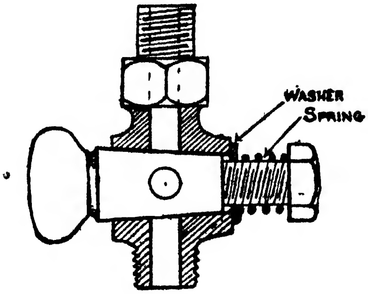


Fig. 23.

tion is the change of trim as the fuel is used, but this may be compensated for by a second tank aft.

The tank (Fig. 22) should be fitted with a receptacle (A), which may be a casting or worked up out of copper.

For convenience in leading the supply pipe to either side of boat as may be necessary, a facing is fitted on each side of the sump, and the one not in use may be plugged up.

Sweated into the end of the supply cock is a

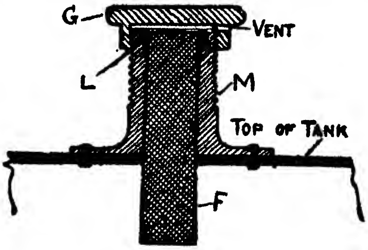


Fig. 24.

piece of copper tube, having its end soldered up solid and with a number of very fine saw cuts in it to prevent the entrance of dirt.

F (Figs. 22 and 24) is a gauze wire strainer for filling, and consists of a frame of stout wire sweated into a flange (L), which drops into a recess in the filling connection (M).

G is a cap with deeply milled rim, which can be easily grasped with cold or wet hands.

The filling connection (M) is made of sufficient length to reach through the deck so that the cap may be easily removed from outside, a neat, tight-fitting brass ring being screwed down on deck round it to make all watertight.

A small vent (V) is drilled through the cap to admit air, and care must be taken that this is kept free, as if it becomes choked a partial vacuum will be formed and the fuel will not run down to the carburetter. (N.B.—When pressure feed is employed, the vent hole must not be drilled.)

Another arrangement of filling pipe and strainer with deck connection is illustrated in Fig. 40.

It is an advantage to have a gauge glass fitted, but when this is done it must be very well secured to prevent any risk of leakage. If the round glass pattern is used, it may be made tight by packing the glands with soft cotton and soap well rubbed in.

A gauge glass of the Klinger type is preferable, and may consist of an oval facing (K) (Fig. 22) riveted to the tank and tapped to receive the securing screws which hold the outer rim and plate-glass; it should be at least ⅛in. thick, and the joints should be made with thin brown paper and soap. It is important that the facing should be filed and scraped true before attempting to joint up, otherwise there is sure to be trouble from leakage.

If pressure feed is to be employed, the two holes (EE) must be plugged up and an internal pipe (H) led down into the tank, the bottom end being solid and having saw cuts as before; but they should only be carried as high as the bottom level of the tank, or it will not be possible to use all the fuel therein. The area of all these slots should be made at least equal to that of the pipe.

Into the plug at the top of this pipe is screwed a bend (J), which in its turn receives a cock. A similar connection on the other side of tank receives the pressure supply pipe, into which there should preferably be fitted a relief valve set to blow at about 5lb. per square inch.

The pressure may be obtained from the engine exhaust by means of a non-return valve, but it is preferable to have a small air pump worked off the camshaft or crankshaft. In either case the pressure must initially be obtained by a hand pump, and a cycle pump answers as well as any.

Fig. 25 illustrates a combined pressure non-return and relief valve for use in conjunction with the pressure supply to the fuel feed tank. A pipe is led from the exhaust system to a double cone connection (M), between the two parts of which is fixed a fine gauze screen (WG), the object of which is to prevent the possibility of flame from the exhaust passing onwards towards the fuel tank. (Where air pressure is used instead of the exhaust, this fitting, of course, is not required.) The exhaust is then led to the valve box, entering beneath the spring loaded non-return valve (A). No adjustment of the spring (S) is required, provided it be not too strong, since its only function is to assist the valve in closing. Having passed the valve (A), the gas is led away through the connection (O) to the top of the fuel tank. Above the non-return valve, and in the same box, is a spring-loaded valve (C), which, by means of the screwed spindle (R) is set to lift when the pressure desired in the tank (from 2lb. to 5lb.) is exceeded. The gas then escapes through the orifices (P). Provision is made for turning the valve on its seat when desired to keep it tight.

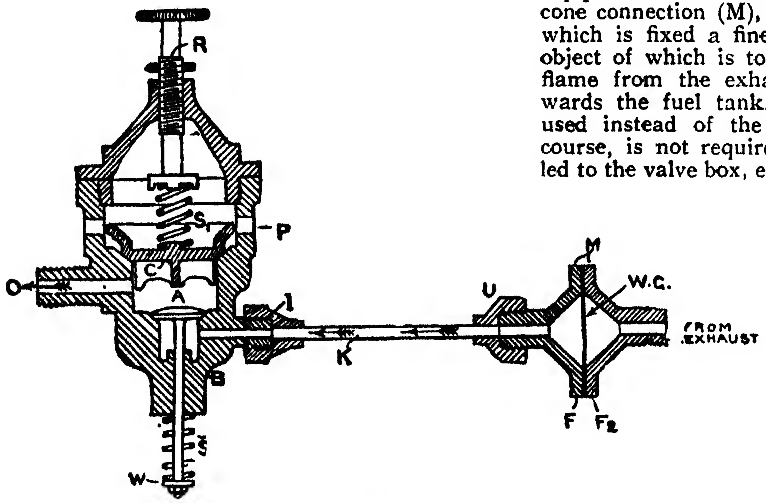


Fig. 25.

Where a large supply of fuel has to be carried, or where the construction of the boat makes it impossible to carry the tank under the turtle deck, it may be placed under seats or lockers, and the fuel either pumped up into a small gravity tank, or pressure feed may be resorted to. In all cases it is of the utmost importance that the tanks should be thoroughly tested to at least 12lb. per square inch water pressure. After testing, all water should be drained out and the inside well rinsed out with paraffin.

Large Powers.

Engines of large power are nearly always fitted in boats having a separate compartment or engine-room, and will require special treatment. If the fuel tank is situated in the same

compartment as the motor, special precautions may be desirable if using petrol. In America it is a practice in many such craft to fit a double bulkhead round the fuel tank and fill it with water, but extra care must then be taken to prevent any water leaking in at connections and joints, and it will be found best to resort to pressure feed. In some cases the tank may be fitted on deck, but this does not commend itself.

Circulating Water.

Water is led to the circulating pump by a strong copper pipe of suitable size, and the position of the inlet fitting on the boat's bottom will depend upon where the pump is located on the motor. If a cock, as shown in Figs. 26 and 27, is used, it should be kept some way up the side, as if the boat is in very shallow water or lying on the mud, the strainer (A) (Fig. 18) and inlet will not become choked with mud, and there will be less tendency for sand to be drawn in. The cock handle should be below the floor boards, and a hand hole cut for access to it; it will then be protected from a chance kick. It is desirable that the circulating pump should have a positive drive, not friction off the flywheel. The pump spindles should be properly lubricated, and the wheels and spindle made of phosphor bronze, preferably running in white metal bushes. All risk of seizing up will then be obviated.

The circulating water, after passing through the cylinder jackets, is generally carried into a water-cooled exhaust receiver (Fig. 27), or, if not thus fitted, into the water-cooled pipe (see notes on "Exhaust").

Exhaust.

If the noise is not objected to, as in racing boats abroad, the pipes may be led separately overboard from each cylinder; but with any other type of boat, some kind of silencing arrangement is essential. If a funnel exhaust is fitted, it should be made long enough to keep the gases out of the steersman's or driver's face.

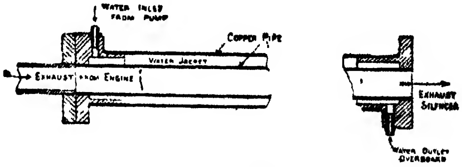


Fig. 28.

In the case of pleasure or cruising boats, the exhaust is now nearly always water-cooled before being silenced, and many makers water-jacket the collecting branch on the motor. Although this entails a rather expensive casting, it is the best method and ensures a cool engine-case. After the gases have been reduced in temperature in such a branch, they may be led to a double copper pipe (Fig. 28), the inner one being of stout gauge, say, 8 or 9, and the jacket about 16 or 17. The gases then pass into the silencer (Fig. 29), and thence overboard. For

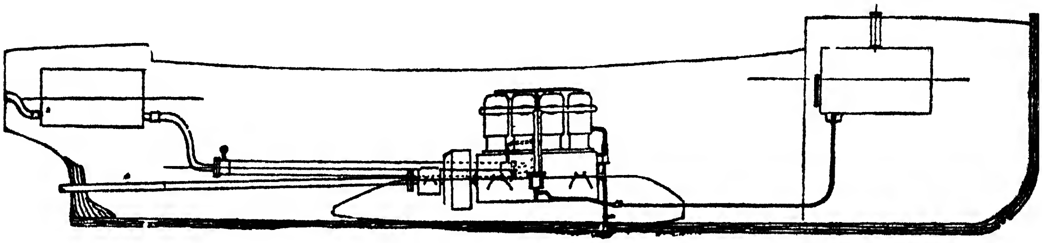


Fig. 26.

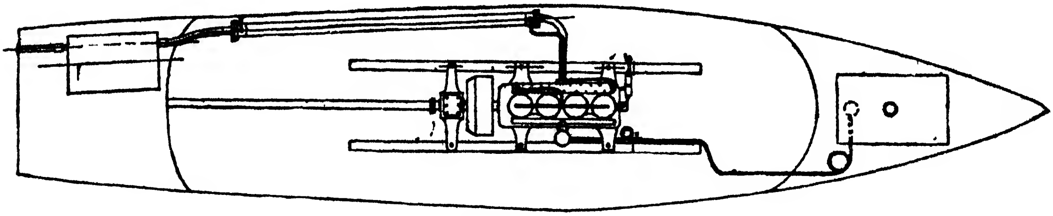


Fig. 27.

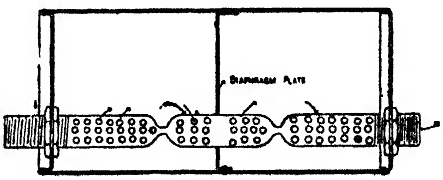


Fig. 29.

other forms of silencer see chapter on "Silencers."

The pipe from silencer overboard may be of steel, in which case it is screwed into a flanged connection (Fig. 31) on the transom. In slipper stern boats, and where the pipe is led out under the counter, a copper pipe may be preferred. In this case a complete turn, or a U bend, should be

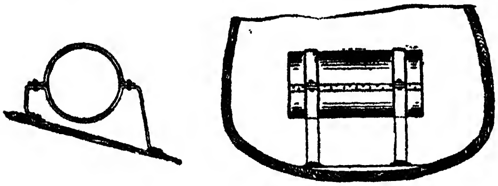


Fig. 30.

taken to prevent risk of water passing back into the silencer.

When the silencer is placed right in the stern of boats with a rising floor, it may be secured in brackets as shown in Fig. 30, the same method, with modifications in the form of the brackets, holding where the silencer is placed in other positions. Strips of asbestos sheet should be placed between the straps and the silencer, or the straps themselves may be wound with asbestos rope, but in any case the silencer must be held securely to prevent any chance of

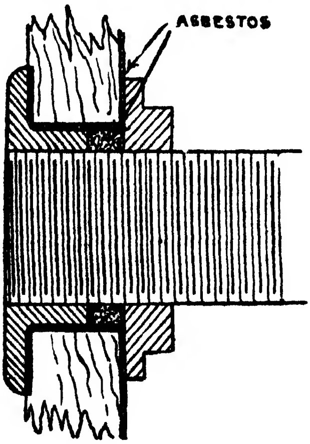


Fig. 31.

its shaking loose or cutting through the asbestos with vibration. Asbestos pads may also be placed under the feet of the brackets, but if there be any chance of water lodging here, they must be well protected with paint, for asbestos rapidly deteriorates in water.

For joints of exhaust pipes or branches on the motor itself, asbestos may be used. Klingerit is excellent in all places for jointing, but in every case care must be taken that all flanges are square and well faced before inserting joints, and then no trouble will be experienced afterwards. A little extra care at the beginning will be well repaid. When running the motor for the first time after being installed, all bolts and nuts of these joints should be tightened up when warm.

Petrol Pipes.

Fuel pipes must be at once out of the way of damage and easily accessible. It is necessary, for compliance with the Thames Conservancy regulations, to fit an expansion joint or a couple of turns in the pipe near the tank and at the carburetter. These turns must be made horizontal, or there will be a risk of air locks in the pipe.

Most boats are fitted with a bulkhead at the forward end, behind which the petrol tank is stowed. The pipe is led to the boat's side, and thence down below the floor boards and aft to

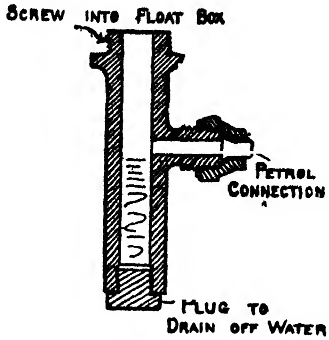


Fig. 32.

the carburetter, a slot being cut in the floor bearers to receive it. A batten may be fixed across in front of the pipe to protect it, and if the locker is used for stowing the anchor or heavy gear, it is well to case in the pipe, or the tank may be completely boxed in, leaving only a hand hole for access to cock and a slot for petrol gauge.

If possible, the fuel pipe should be all in one length, but if this cannot be arranged, the joint or joints must be in an easily accessible position; they are best made with unions securely sweated to the pipe (Figs. 15, 16, 17), with as few bends as practicable, and those which are inevitable should be of large radius. All risks of fire must be carefully avoided, for it is nearly always due to leaky pipes or joints that fire occurs. The fuel pipe must be well annealed after being bent to necessary shape; this is done by heating to a blood-red and plunging into water; of course the ends or parts sweated to connections will not stand such treatment.

A drain or water trap should be fitted on the petrol supply pipe near the carburetter to collect any water which may come from the tank with the petrol. There are several arrangements with this object, the one illustrated in Fig. 32 being intended to screw on to the float chamber of the carburetter.

On no account should lead, iron, or lap-

jointed pipes be permitted; only best solid drawn copper of at least 16 gauge should be used, and all joints, cocks, and connections should be tested thoroughly when fitted. If the union connections shown in Fig. 15 are used, the pipes should be scraped to a good joint, when coned out to receive the cone; it is not enough to depend upon pulling up with the nut.

Lead washers must be avoided in pipe services, as they squeeze out and obstruct the passage of

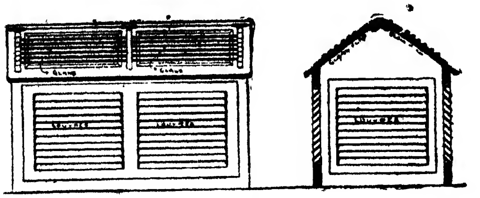


Fig. 33.

petrol or water, and as long as the joint remains tight the trouble is not sought there.

Soap is invaluable for stopping petrol leaks, and may be used with thin brown paper for making joints.

Engine-case.

Unless the engine is placed in a cabin or decked in, it is desirable to have a stout case all over it. This may be semi-portable—that is, the stiles or corner pieces may be screwed to

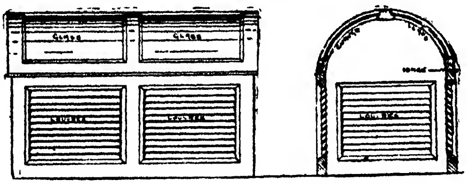


Fig. 34.

the beams, and the after end permanently fixed, as it usually carries control brackets, levers switches, etc.

The sides should be portable, and should be held in position by buttons or hooks.

The general design of the engine-case will depend upon the work that the boat has to do. If for pleasure purposes, it must be neat and

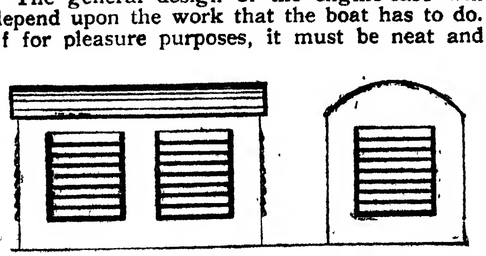


Fig. 35.

ornamental, must serve to protect the engine from the weather, and also to muffle the sound as far as possible.

The wood used may be the same as the boat; mahogany or teak are the best, and should have three coats of best boat varnish. Metal is not satisfactory, and a metal case is more difficult to construct than a wooden one.

In each of the forms of motor casing illustrated it will be seen that the sides are entirely composed of louvres like a Venetian shutter, whilst as to the casing shown in Fig. 33 (side and end elevations), each of the four sides may be removed separately if desired to give free access to any part of the motor.

The first example is built of mahogany or teak, and is very similar to a yacht's skylight in its general form at the top, as, like a skylight, it has two hinged flaps, one on either side, glazed with stout glass and protected with brass rods in the usual manner. The inside of

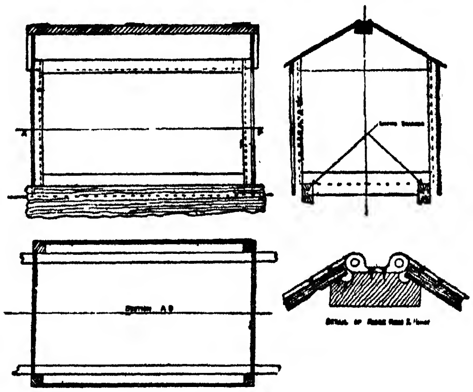


Fig. 36.

the casing near the exhaust piping and silencer is lined with stout asbestos board to prevent the heat damaging the wood.

Another variety of this style of casing specially designed for river boats is the one shown in Fig. 34. This merely differs from the kind just described in having the glass top in the form of an arch, the whole of which is hinged on one side and can be turned over to get at the motor. Like the previous one, the sides are fixed and the whole case must be removed bodily. It forms a very handsome casing, but the curved glass arch naturally renders it rather costly.

Fig. 35 shows a light sheet metal case very similar in design and construction to an ordinary motorcar bonnet, except that for marine purposes it must be made of brass or copper instead of steel, unless the latter is galvanised. A galvanised steel casing, by the way, looks very well if it is neatly mounted in brass.

On the whole, a metal casing is not so shipshape or so generally satisfactory as one of wood, not only because it is more likely to rattle

in a seaway, but chiefly because it is much more susceptible to damage from a chance blow than would be the wood casings, which would only show a scratch, whereas an equal blow would probably dent the thin metal.

All three of these motor covers are quite efficient and can be relied on to keep off wet and dirt, whilst, with regard to cost, the galvanised steel and the plain wooden covers without glass would probably be the cheapest, the cost of the others being regulated by the quality of the wood and the amount of labour expended on them.

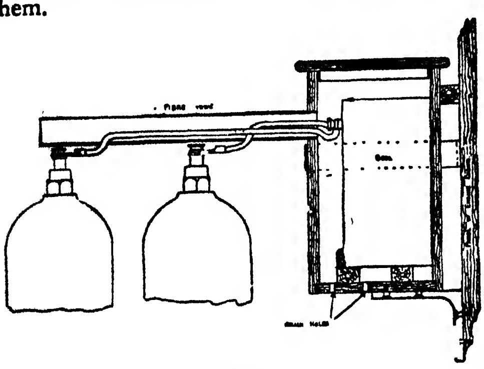


Fig. 37.

Details of the Engine-case.

To deaden sound, the inside, after being painted, may be lagged with thick felt and covered with asbestos held in position round the edges with thin strips of brass about ¾in. wide screwed through to the wood. If this, although very effective, appears too costly, asbestos millboard or uralite can be substituted. The case should be made as large as the boat will allow to give free access to all parts of the motor.

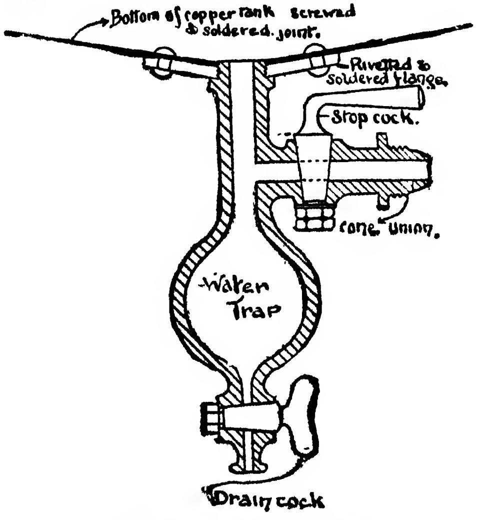


Fig. 38.—Fuel tank sump or drain.

Nothing is more annoying than trying to tighten a remote nut when the casing is in the way of the spanner and hand, while the boat is pitching about in a seaway. The lid, in small motor cases, may be flat and will serve as a table.

In larger cases, however, a ridge piece should be fitted across the centre fore and aft, as in Fig. 36, and two flaps hinged to it, waterways being provided in the ridge. A strong double hinge may then be placed across the two flaps, which will minimise the risk of their being broken. The whole should be made as readily removable as possible. The forward end and two sides may be taken away in one piece after the ridge piece is removed. All parts should be screwed together with cup-screws (i.e., screws whose heads fit into small brass cups let into the wood).

It will be necessary to ventilate the case; this may be done by a number of holes bored in the ends or sides, or, better still, holes may be cut out and brass ventilators fitted, their position

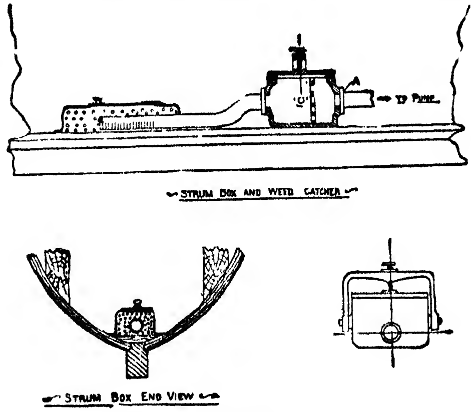


Fig. 39.

depending upon circumstances. If a very hot exhaust pipe has to be reckoned with, one or more ventilators may be inserted in its neighbourhood.

Where high-tension ignition is employed, it is a good plan to fit the coil and battery in boxes inside the case (see Fig. 37), having two small battens at bottom for the coil to rest upon, and small holes for the draining away of any water which may accumulate. This will ensure the better protection of coil from wet and short circuiting. The wires may be led into a rubber or fibre tube which is jointed into the box.

Bilge Pump.

For sea-going boats it is very important that a pump should be fitted to work off the engine; a small plunger pump or a semi-rotary is often used. If a pump of the latter type is employed, the driving lever may be made detachable, and the pump worked by hand when the engine is not running.

The suction must be carried into the lowest

part of bilge and well protected with a strainer, closely fitting to bottom of boat and provided with a lid (Fig. 39). The end of the pipe should be plugged up solid and saw cuts made in the under part.

Too much stress cannot be laid upon the bilge pump installation being as complete as possible, as water rising and touching the flywheel will be thrown all over the engine and lead to short circuiting, besides the extra weight of water seriously impeding the boat.

To prevent this, it is advisable to fit a case all round the flywheel. It can be made in two halves, the lower being made watertight, so that in the event of water rising it will not reach the wheel. A two-way hollow bottom cock may be fitted, with one pipe leading to the bilge and the other into engine tray.

The floor boards should all be removed before the trial trip, and at frequent intervals afterwards, and all dirt, waste, chips of wood, etc., removed.

Rotary pumps are not suitable for bilges, as they are very liable to become choked. In the case of large boats, it is well worth fitting a weed box in addition to the strum (A, Fig. 39). This is a cast-iron box having a loose perforated plate fitting into grooves in the sides of box, the dirt, etc., being deposited on inlet side. The cover is easily removed by unscrewing the handle and lifting off lid. The joint is made airtight by indiarubber let into recess in top of box.

The Engine Board.

An extremely useful feature in the perfect installation of power in a motor boat is unquestionably the engine board—almost equivalent to, and even more useful than, the dashboard of a car. Wherever it can be employed it will be found to simplify matters and to "clear up" the boat considerably. It is best placed either on the after end of the engine casing, if the casing be a fixture, or else be erected at the rear end of the engine at a sufficient distance to allow it to be made a permanency and yet not to interfere with the accessibility of any part of the mechanism.

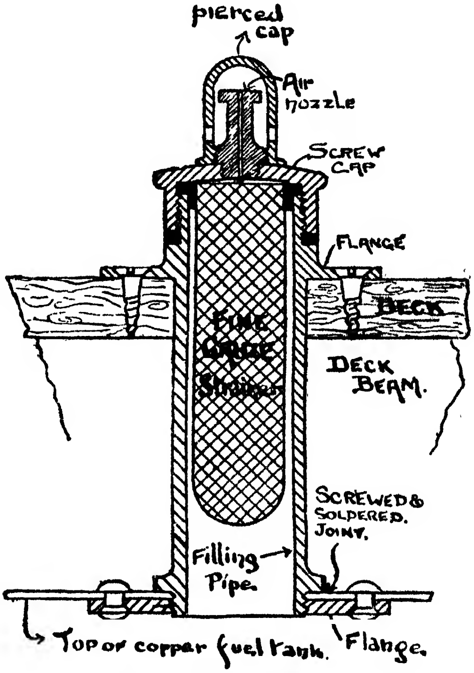


Fig. 40.—Fuel tank filling fitting.

This is not always easy to arrange, but it is well worth striving for. On the engine board should be fixed a box for the accumulators and the coil, the oiling apparatus, the quadrants for the engine controlling levers, and any instruments and devices that belong to the mechanism

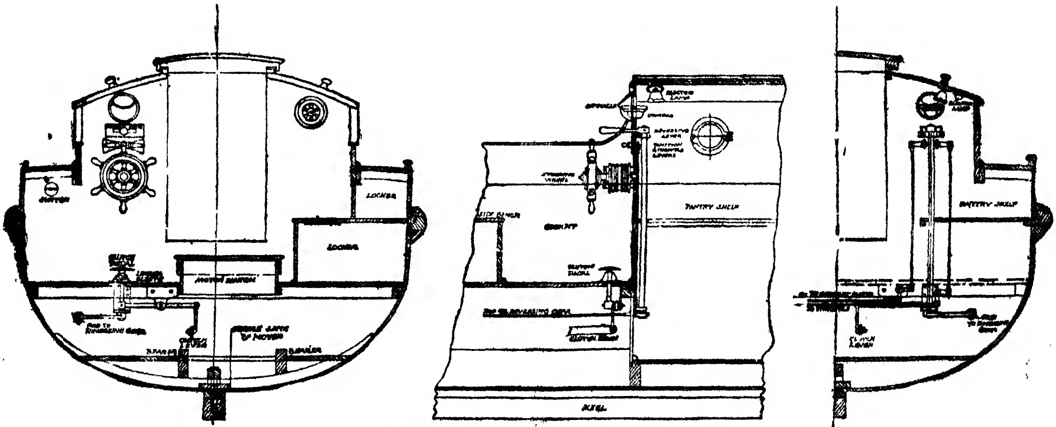


Fig. 41.—The engine and vessel control arrangements in a motor cruiser.

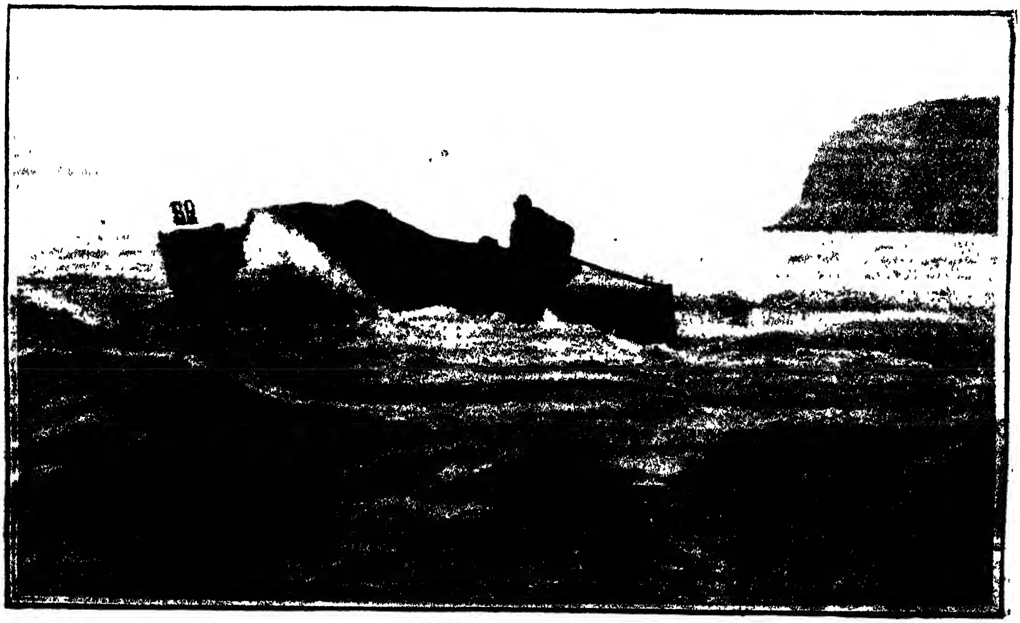
or are fancied by the owner. To have the ignition apparatus on such a board is a great convenience, as it saves the batteries being stowed in a locker, it shortens the wiring and thus reduces short-circuiting troubles, and usually with a well-fitting and watertight box the component parts are much better protected from damp. The board is a fit and proper place for all levers controlling the engine, and shorter connections are entailed, whilst greater efficiency in the connections is more easily secured. Boxes for tools in frequent use and for hand-oilers, rags, a flask of methylated spirit, etc., can usefully form the lower portion of the board. The engine board, in fact, has the happy advantage of bringing a number of contributory details of the petrol motor to a focus, whereas, without it, they are apt to be distributed, with the result that they are often rendered less accessible and are seldom so advantageously placed out of harm's way.

Controlling Arrangements.

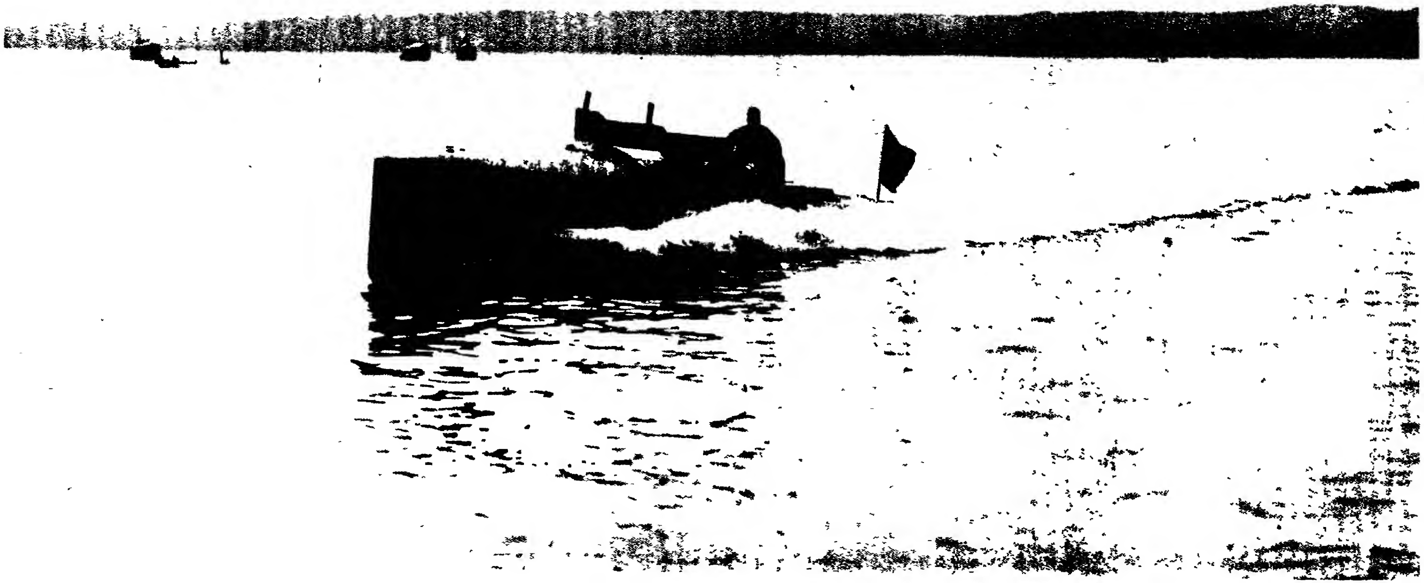
In connection with the matter of engine control, the actual control of the boat itself might be considered. It is essential that when the boat is being designed every care should be taken to bring all the controlling gear within easy reach of the helmsman, who will probably be engineer as well, except in the high-powered racing boats, which must carry a regular engineer in addition to the helmsman, although even then the helmsman should have control of the clutch and reversing levers.

It is, therefore, most important that the helmsman's seat should be so placed that he is alongside the after end of the motor, with clutch and reversing levers close to his hand or foot, and with the steering wheel slightly to one side of the motor casing and right in front of his seat. It is usual to place the wheel on the port side of the boat alongside the motor, with the helmsman's seat close abaft it, so that he can get a clear look-out along the port side of the boat, which is, of course, the side next to all the boats she meets. For this reason the forward position of the motor in the boat has much to recommend it, on account of the clear look-out ahead obtainable from the seat alongside the motor, as, with the passengers aft, the man in charge is not obliged to spend half his time trying to peer round the shoulder of someone sitting just in front of him, especially as it seems impossible to persuade the average passenger that one can neither see through him nor steer without a clear view ahead.

In cabin cruisers it is usual to arrange the control fittings on the after-cabin bulkhead. Fig. 41 illustrates a good typical arrangement (as installed in the converted lifeboat "Tomoyé"), which, however, must, of course, be modified in other craft to suit varying conditions. In any case, and for a sea-going vessel particularly, provision should be made, by a weathering board or otherwise, to protect switches and such-like parts.



"Lanturlu IV.," one of last year's racing cruisers with a geared-down propeller.



"Dixie II.," a 40ft. 270h.p. racer that won the B.I. Trophy Race in 1908.

INSTALLING A MOTOR IN A SMALL BOAT.

A Practical Chapter for Novices.

There are many who would join the brotherhood of marine motorists but for the expense involved in the purchase of a complete motor boat. It is true that small and low-powered launches can be purchased very cheaply now, and second-hand craft more cheaply still, but, after all, there is a certain satisfaction in equipping a boat for oneself.

There will be many who would do it if they knew just how to go about it, and this article, detailing the particulars of an actual conversion, is intended to afford that information.

The boat converted was not of a design that one could call especially suitable for the purpose, but this fact serves to emphasise what can be done in the way of converting quite an ordinary craft, such as any man who does a little boating may already possess, into a very pleasurable motor dinghy.

The boat in question might be termed a skiff-dinghy, and was built for work in a harbour; consequently, it is somewhat heavy. The length is 13ft., beam 5ft., and draught 18in. She is clincher built of elm.

Her lines are as shown in the body, sheer and half-breadth plans (Figs. 1, 2, and 3).

There was one feature about the boat which saved a lot of trouble with regard to the fitting of the necessary stern tube for the propeller shaft—the sternpost and dead wood were of sufficient thickness already to admit of the requisite stern-tube hole being bored, thus obviating the necessity for fitting any reinforcement in the way of side cheeks on the sternpost or a block at the stern within the hull, a method sometimes adopted when the sternpost is less than 2in. in thickness.

A Suitable Engine.

The first step after deciding to instal a motor in the boat was to look about for a suitable engine, bearing in mind that a power of from 2½ to 3½h.p. would be about the best for the type of boat in question.

Now, the draught of the boat greatly affected the choice, more particularly for the reason that, not desiring to add to the keel to prevent the possibility of grounding on the propeller, it was essential that the propeller should be of small diameter.

This would, consequently, have to make a fairly high number of revolutions per minute, the pitch being moderate in order to ensure the engine being easily started, since it was the intention, for simplicity's sake, to couple the engine direct to the propeller shaft without any gearing down or free engine and clutch.

Of course this meant that a reverse would have to be dispensed with, but it is the writer's experience that in a small boat one does not require to go astern under power.

A small propeller, to be effective, must revolve at from 800 to 900 revolutions per minute, fortunately about the speed at which many small petrol four-stroke engines are designed to run economically, thus admitting of the possibility of selecting a suitable motor from the miscellaneous sales columns of "The Motor Boat" or other motor Press.

The engine for the purpose must have a water-cooled jacket and head.

There are one or two motors especially well adapted for use in a boat of the size mentioned on the market of 3h.p. or 4h.p., and designed for marine work. If cost, however, is a principal consideration, it would probably be better to select from the columns of one of the motor papers, as the writer did, a good second-hand water-cooled motor of the desired power and number of revolutions by a maker of repute.

It is most essential before settling upon any particular make to be sure that it is suitable to receive the necessary attachments or brackets for securing it properly to a substantial wood bed, which has to be fitted for its reception in the boat.

Either have the engine on approval, or, if a new one, obtain drawings showing a plan, front and back elevations, and side views.

You will then be able to see, among other things, at what height above the floor the centre of the driving shaft will come.

Do not cut the space under the engine too fine, or the bearers of the bed will come out small and weak and make the whole less get-at-able.

In the case under description, the engine purchased being one not originally designed for boat propulsion, angle brackets were required for attachment to the bed, and they were designed as shown in Fig. 4, and cast in iron—two from a right-hand pattern and two from a left-hand one.

Anyone installing a motor in a boat, however

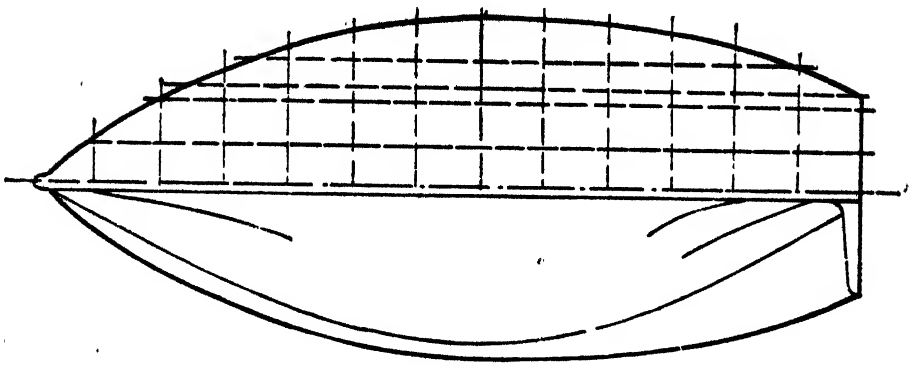


Fig. 1.—Half Breadth Plan.

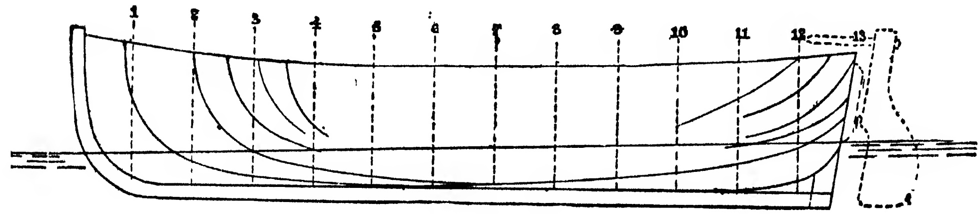


Fig. 2.—Sheer Plan.

humble, may be recommended to prepare drawings showing longitudinal and cross sections at the after end of the boat, the sections being one at the proposed centre line of the engine and the other at the transom.

The engine purchased can then be drawn out carefully on these sections, and the best position for installing the motor can immediately be arrived at.

Position in the Boat.

A word about the best position will not be out of place here.

In a craft that is likely to be suitable for converting there is generally, perhaps, but one position in the sternpost where the propeller shaft could be put through, having due regard to the draught of the boat and the diameter of the propeller.

Using this point as a fixed one on the after face of the sternpost, and the centre of the motor shaft (after end) at the lowest level at which sufficient clearance can be obtained, the line joining these points will give the correct run of the propeller shaft throughout.

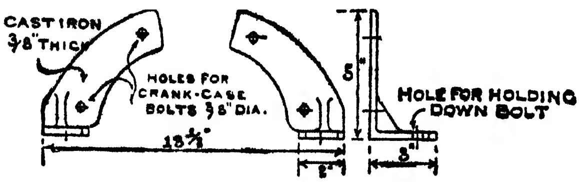


Fig. 4.

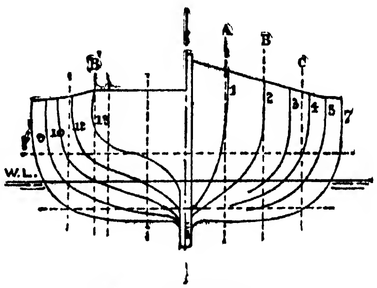


Fig. 3.—Body Plan.

With due regard to the points before-mentioned, the lower the engine is the better, as it will permit of better lubrication, the crank case and cylinder then coming out in a more vertical position.

If a Hookes's or Universal joint between the engine and propeller shaft be employed, the former could be installed in a perfectly vertical position, which is, of course, better, but in the case under consideration such was not used, and, with due thought and care, very little declination need be given, as shown in the illustration of the actual case in Fig. 5.

The Engine Bearers.

Having fixed upon the line of the propeller shaft, the wood bed, or bearers, should be prepared. Teak is a very good timber for this, and if

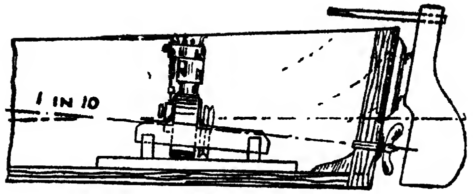


Fig. 5.

the reader will look at Fig. 6 he will understand far more readily than from a written description exactly how the bed in this instance was framed, and the type can be taken as a good one to adopt in general for almost any case.

The scantling employed is 4in. by 2in. teak framed together with ⅜in. diameter coach screws. Directly upon the keel a piece of teak 4in. by 2in. extending from the sternpost to the forward end of the engine bed was secured by ⅜in. diameter coach screws after bedding it in white lead.

Upon this fore and aft piece the frame was secured by further coach screws. Steadying blocks at the sides were interposed between the hull planking and the frame, insulated from vibration by stout sheet rubber.

The top of the motor frame is given the same declination (worked out as before described) as the propeller shaft, the height of the bed being previously determined on the drawing of the cross section of the boat, and, perhaps as a check, in the boat itself by means of a cardboard template, or pattern, of the crank-case and engine cylinder outlined.

The Stern Tube.

When the bed is fixed, wood or sheet iron guide plates should be temporarily secured for steadying the long auger that must next be used for boring the stern-tube hole. One of the guides should be fixed as far forward as possible and the other as far aft as convenient. Each must have a hole in it to admit the auger shaft, which should be a fair fit. The centre of each of these holes has to be on the centre line of the propeller shaft.

Without further explanation it will, no doubt, be readily seen that, by this contrivance, absolute accuracy is ensured in performing an otherwise difficult job. If the hole for the reception of the stern tube is not bored truly in the first instance, no end of trouble is incurred in installing the motor correctly. The inevitable result will be trouble from hot bearings at best, and, if the alignment is very bad, the whole structure may be seriously strained, or the stern tube may leak badly. Though it sounds simple enough to bore the stern tube with the help of guides, as already explained, it is, if the shaft is to be nearly horizontal so that the auger keeps close to the bottom of the boat, a knuckle-breaking job, and great care must be taken to fix the guides very firmly, otherwise the auger may be levered up from below and shift them, imperceptibly to the eye, but sufficiently to throw the tube out of line.

Fig. 7 shows the auger arranged in position for boring on the system described.

If the engine it is intended to instal is from 2 to 4h.p., the propeller shaft may be as small as ¾in. in diameter, provided the shaft be run at from 700 to 900 revolutions per minute. The diameter of the outside of the stern tube gland will only be 1¾in. if the design shown in Fig. 8 is followed.

The arrangement shown is the most simple that can be adopted, and has proved very successful in one or two boats fitted with it.

The size of the hole to be bored in the sternpost of the boat should be about 1-16in. in excess of the diameter of the tube, to admit of it being surrounded by a thin film of white and red lead. If the surface of the stern tube casting be left rough from the sand (not turned bright) it will result in a thoroughly watertight fit.

No description beyond stating that the tube fittings should be of bronze and yellow metal throughout, including set and coach screws, is needed, as the drawing in Fig. 8 is sufficiently detailed.

The stern tube gland being smeared with thick red lead, it should be pressed into its final position and coach-screwed. It is preferable to have the flange of gland recessed into and flush with the sternpost.

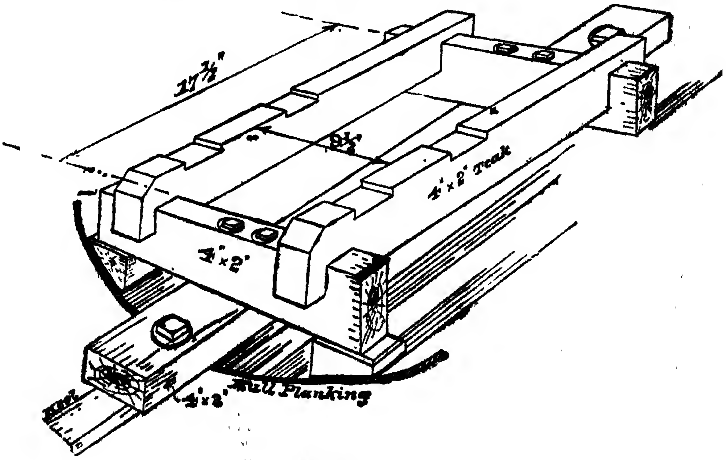


Fig. 6.

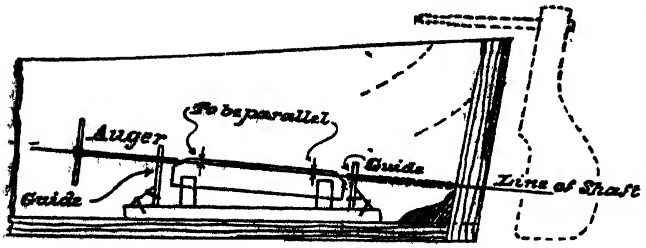


Fig. 7.

Connection between Motor and Propeller Shaft.

The exact position the motor is to occupy on its bed having been previously settled, the next step to consider will be the form of the connection to be employed between the motor and the propeller shaft, so that the length of the shaft can be accurately determined now that the tube is fixed. To see at a glance the method employed in the case under notice reference should be made to Fig. 9, which shows the engine as purchased, with the exception of the lubricator, which was added by the writer.

Fig. 10 shows the design of the coupling fitted subsequently. The principle generally would be applicable in most cases, but care must be taken that the full thrust is put on the thrust-block bearing before the coupling is tightened up, so as to prevent any end pressure coming on the motor bearings. To obviate the possibility of this occurring, either a square-end shaft, fitting into a square hole in which lateral movement can take place, is adopted, or else two driver plates are sometimes employed, as shown in Fig. 11. The form of the propeller shaft drive determined, the length of shaft required can be measured right through the stern tube, allowing, of course, sufficient clearance to admit of adjustment to the stuffing-box, which will be required once or twice in a season.

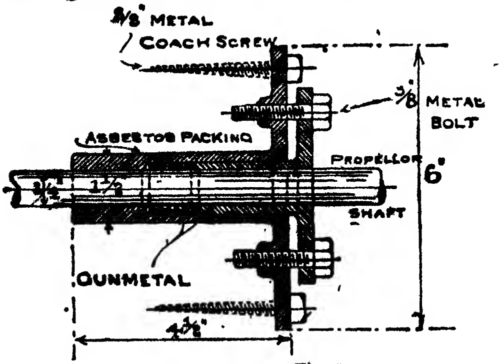


Fig. 8.

The Propeller.

Fig. 12 indicates a suitable means of securing a propeller having a boss of normal dimensions.

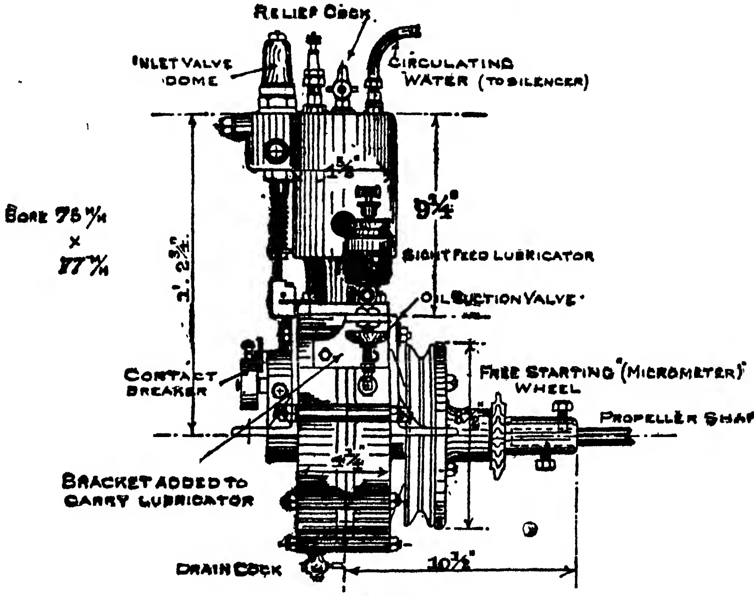
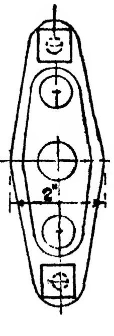


Fig. 9.

A few hints on the subject of a suitable propeller may be useful. The question is a difficult one, and one cannot expect to hit upon a propeller at first that will give the maximum possible speed for the length of boat, and power of engine, unless one has had considerable experience.

The writer has tried several of different diameters and pitch on the same boat. The one shown in Fig. 12 has given the best results, both in speed and lack of vibration.

As an example, showing what a difference the lines of a craft and revolutions per minute of a shaft make, Fig. 13 has been prepared. This indicates the most successful



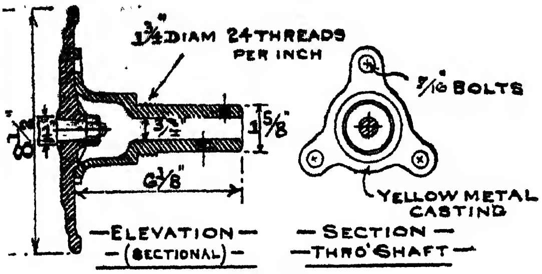


Fig. 10.

propeller the writer designed for a 16ft. boat he had built, which was fitted with a 3h.p. engine, driving the propeller shaft at 550 revolutions per minute through gearing.

Regarding propellers an amusing quotation, received by the writer, which serves to show that even those professing to make propellers are not fully acquainted with their virtues

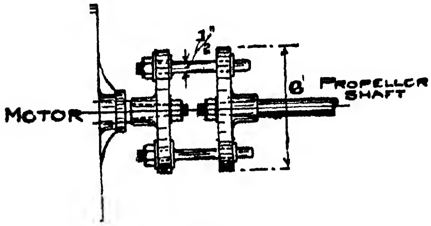


Fig. 11.

reads: "14in. propeller blades run about 5in. on flat and about 3in. or 4in. across. Pitch, *if any desired*, usually 1in. to 2in. In bronze, price £........."!!!

Possibly this firm combat the theory of the screw as applied to the propeller.

There can be but little doubt that a three-bladed solid propeller is the most satisfactory; it gives a more even resistance than a two-

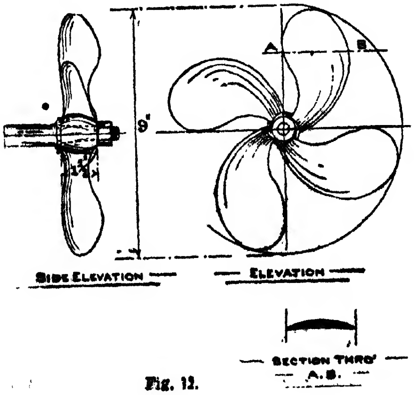


Fig. 12.

bladed one, and, consequently, less vibration. It has an advantage in the case of an accident to one blade in that it has two left which will work without much loss in speed.

A two-bladed propeller has the one advantage that in the reversing form if offers a simple mechanical means of moving the blades, but, as stated at the commencement of this article, it is not necessary to run a small boat astern under power.

A reversing propeller having the means of bringing about a variable pitch has the disadvantage that the blades cannot be of the shape that will give the maximum efficiency in any one position if they are of the form best suited for the average angles they may be set to, forward and reverse.

The Thrust Bearing.

The next item for consideration is the thrust-block bearing. The design recommended for moderate powers is illustrated in Fig. 14. It is extremely simple, and has stood the test of time in more than one boat.

Fitted as near the shaft coupling as possible and serving, as it does, as a horizontal bearing as well as a thrust, no other support between it and the stern tube is required for the shaft. A ¾in. diameter shaft in gun-metal can be allowed an unsupported length of not more than 2ft. 6in.

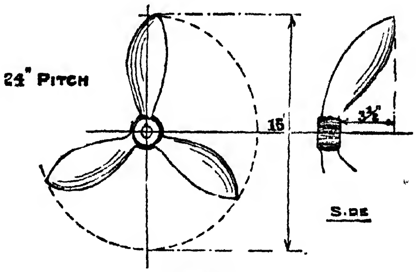


Fig. 13.

Various Fittings.

In Fig. 9 it will be noticed that a small sprocket wheel is fitted on the shaft coupling. This is a Micrometer motorcycle free-wheel, and forms the drive for the starting arrangement shown in Fig 15. This form of free-wheel device was selected as being the least likely to get out of order, since the falling of the pawls into the ratchet is dependent on gravity and not springs, which might rust up in such a position, exposed to salt air perhaps.

The fixed wheel and chain are of the ordinary cycle type, mounted on a gun-metal handle and centre, with a flange adapted for securing it to a bracket from the engine.

A pump for circulating water through the

engine jacket and silencer casing next demands attention. In some of the sets specially manufactured for marine work the pump drive is arranged for on the forward side of the crank case, but in adapting another engine to a boat it is generally most convenient to fit it to the propeller shaft in about the position indicated in the general arrangement plan (Fig. 18).

From personal experience the best pump for use in a boat is that known as a geared pump. It is a little machine that requires but occasional attention in the way of lubrication, and works most silently, since there is no need for such a high velocity as in the case of the small centrifugal pumps. Fig. 16 shows the pump. Several firms supply a pump of this pattern, and some of them will equip it with sprocket wheels and chain, to suit the speed one's engine runs at, at a very moderate cost.

The silencer has to be considered next. This is a water-cooled one for the sake of the

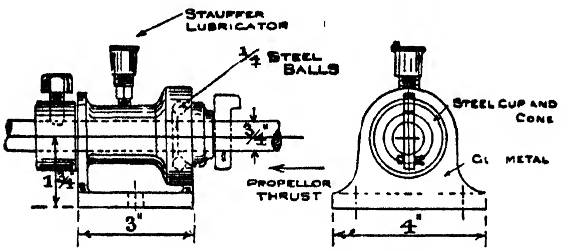


Fig. 14.

silence gained thereby, and safety in not having a heated chamber in any position in the boat likely to be a source of annoyance and danger. The firm (at Salisbury) which supplied the pump make a good silencer entirely of yellow metal, which is, of course, very desirable, but it is quite within the capabilities of a good local tinsmith to make one like that used in the boat being described, which is of the design shown in Fig. 17, and of galvanised sheet iron coated inside the water space, after completion, with " Siderosthen "—a non-corrosive paint.

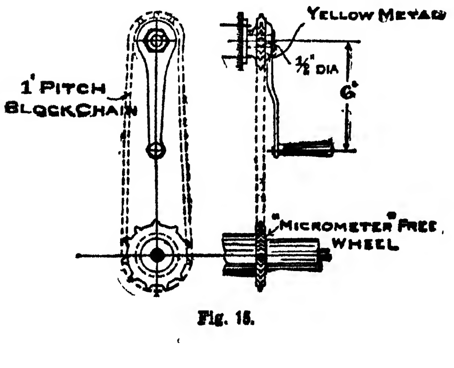


Fig. 15.

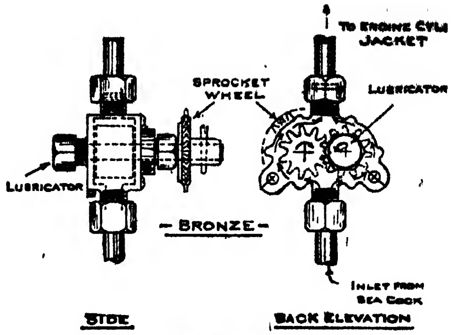


Fig. 16.

The circulating water is passed around it after coming from the motor cylinder jacket, and is discharged through a sea connection in the planking of the boat just above the water line near the stern.

The circulating water intake is a simple straightway plug tap, with screwed end and large flange brazed on, which forms a seat on the boat's planking, india-rubber insertion being used between the flange and planking. A thin brass nut is used on the screwed end of the tap to draw it up to a watertight joint on its seating from the outside. A piece of brass gauze is tacked on the outside, over the end of the tap, to act as a strainer.

The inner end of the tap is grooved to take a rubber hose pipe.

The outlet may be a similar fitting exactly if below the water line, if not, a plain connection without tap will suffice.

The exhaust pipe between motor and silencer should be bound round with asbestos rope to avoid damage by heat to anything that might come in contact with it.

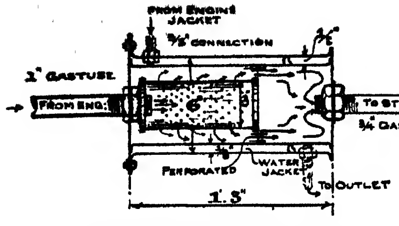
The arrangement and size of pipes, both circulating and silencer, is shown in the general plan, Fig. 18. This will vary naturally with the design of boat which is being fitted with power, but not to any great extent.

The Fuel Tank.

Position for, and design of, the petrol supply tank may next claim attention. It is perhaps most often convenient to fit it in the bow of the boat under a decked forepart, in order to give sufficient fall to the supply pipe to carburetter.

In the boat illustrated in Fig. 19, a small locker is shown in the stern sheets and the tank located there.

Since about 60 miles, at 6 miles per hour, can be done in a 14 to 18ft. boat installed with a 3h.p. four-cycle engine on two gallons of petrol, it is hardly worth while making provision for a



PART SECTIONAL ELEVATION

Fig. 17.

tank that will carry more than, say, twice that amount, i.e., one measuring about 1ft. 3in. by 1ft. 3in. by 6in. deep. In the craft described only a 2-gallon tank is used, and that has been adapted from one of the cans the spirit is sold in. Laid on its side, it makes a very convenient form of vessel for fuel for such a small boat as the writer's.

The fitting of a Davison petrol gauge and one of that firm's fillers with hinged cap and strainer combined is recommended, as both will soon save their small cost in the amount of trouble avoided. The hinged cap has an excellent toggle fastening, and is also provided with a screw-down vent valve. Fig. 20 illustrates the supply tank complete.

For the supply to the carburetter, copper piping is the best, as a composition pipe is liable to develop a leak.

The carburetter should be one having a float

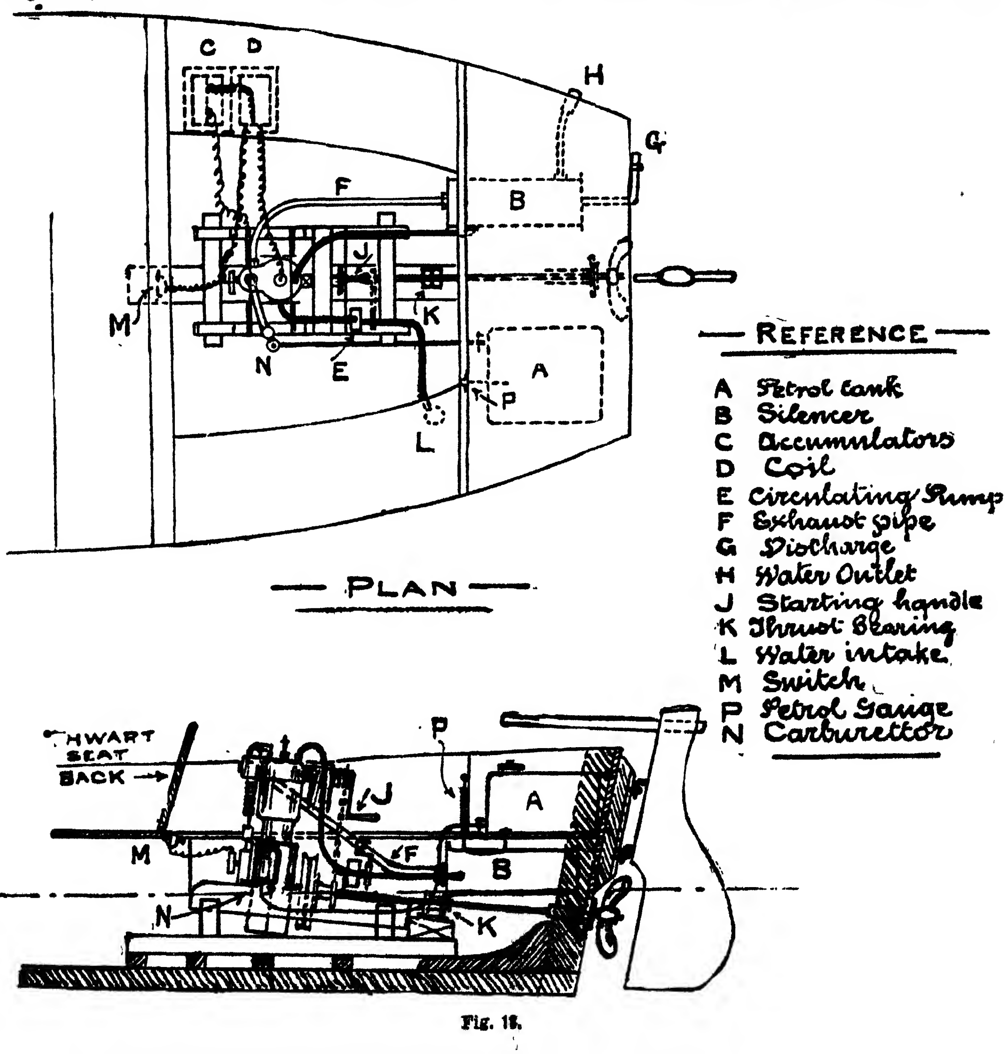


Fig. 18.

Fig. 19.

chamber, and fitted with a small tray to intercept any petrol that may overflow when flooding to start. In the writer's boat a jet carburetter of usual type is employed, and it has given every satisfaction.

Be sure in installing this fitting that, at the very worst case in the trim of the boat, the spray nozzle is well below the level of the supply tank. If not, on a choppy sea one may get an annoying stoppage.

The best plan is to put the supply tank as high as convenient in the boat and, if necessary, to lengthen the induction pipe to suit.

Ignition.

The ignition device that will be most generally available is probably high tension, by means of a coil and accumulators. Magneto low tension is preferable if the various parts are well protected from the action of salt air and spray (supposing the craft to be used in the vicinity of the sea) as the system does away with all the uncertainty connected with secondary batteries. If the former is adopted, it should be arranged as near the motor as possible, so as to avoid loss by leakage through long high-tension cable. Such a position will probably be in a locker on, or under, the seating, preferably on the starboard side, which obviates stepping over

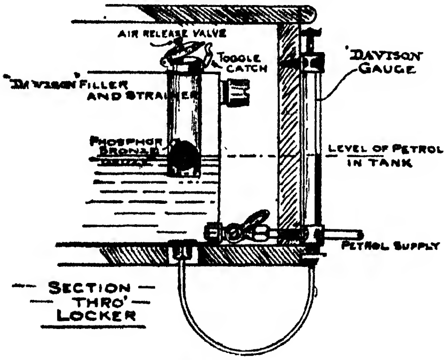


Fig. 20.

any cable connections in going to the usual position for steering if by hand tiller.

Should the arrangement of seating permit, a very suitable place for the coil and battery is in a locker or receptacle formed behind the amidship thwart seat-back.

The reader is referred to Fig. 18 for the arrangement adopted in the writer's boat.

It is well to remark here that it is not advisable to arrange the battery and coil close to the petrol supply tank, as the sparking at the coil trembler might possibly ignite any vapour that would arise should a leak of petrol occur. The most suitable form of switch is the ordinary every-day type used in connection with electric incandescent lamps. It is conveniently placed in the low-tension circuit between the engine frame, or "earth," and the so-called negative terminal of the battery.

The writer recommends the use of two accumulators, if a battery be used, so that one can take the place of the other in the event of a failure.

Alterations.

Turning to the boat itself, a few minor alterations were found necessary, chief among which was to reduce the width of the rudder a little, from the inside, to admit of sufficient clearance for the propeller.

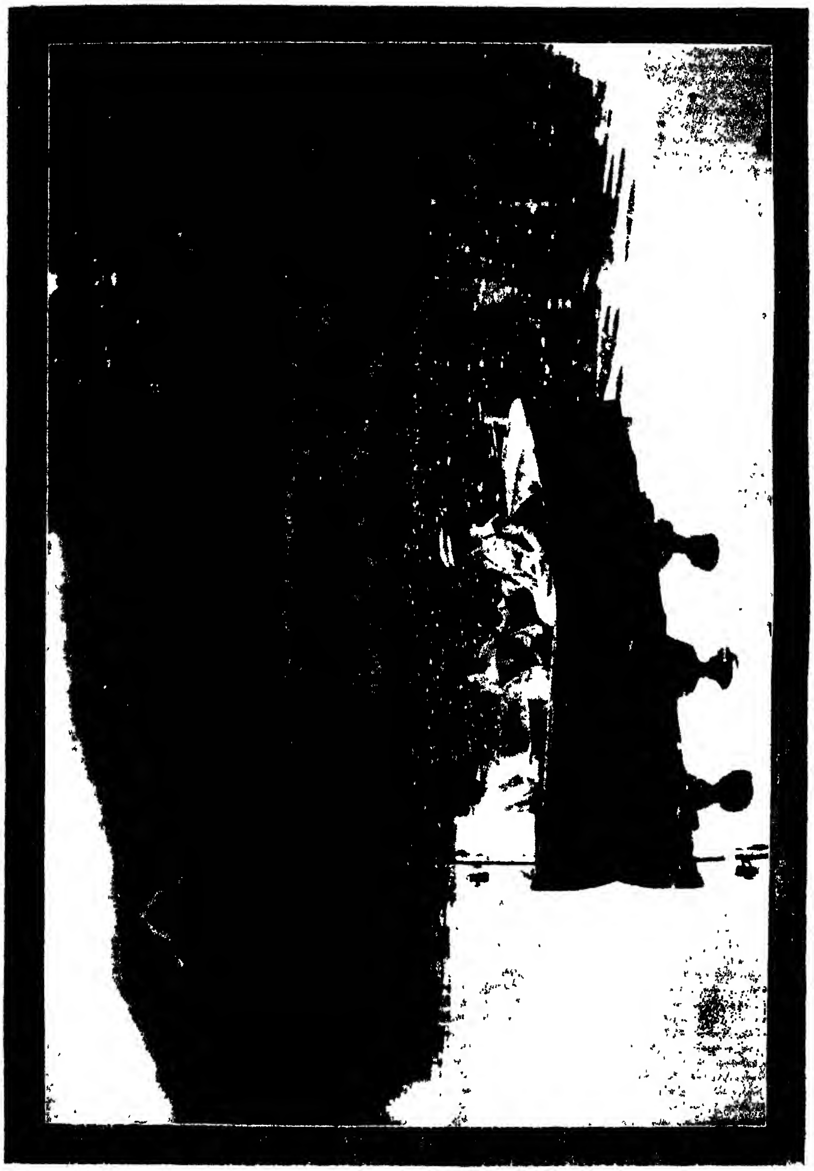
The Result.

The speed obtained is an average of 5½ miles per hour in slack water on a consumption of petrol equal to 30 miles per gallon. One accumulator (20amp. hr.) when fully charged gives a good spark for about 80 miles before requiring recharging, provided that distance be not done in instalments spread over too long a time, as a battery will discharge slowly, even if not in actual use.

As to reliability, the writer has no hesitation in going for a fishing cruise, outside the harbour, extending over six hours' continual running. The arrangement and design of the motor permits of the boat being slowed down to a steady speed of three miles per hour, and the boat has proved a very useful craft for a little sport in the way of "mackerel whipping."

In conclusion, it will be well to answer a question anticipated from many readers—what was the cost? This, for the complete installation, came out well under £20, not including the boat already at hand.

A reproduction from a photograph of the little craft as she appeared after her "conversion" is given on the next page.



The "converted" boat. (See previous page.)

COMMERCIAL MOTOR VESSELS.

Some Notes for the Guidance of Those Considering the Adoption of Motor Propulsion for Industrial Craft.

Although the motor has only been with us a comparatively short time, it has already proved what brilliant prospects it has before it in the direction of commercial utility, and commercial motor vessels are doing yeoman service in many places abroad, where suppliers and users know how to select and instal motor power in a manner suited to the special needs of commercial service.

In considering the application of the motor to the propulsion of commercial types of vessels, the problems to be faced are quite other than those involved in motor-propelled pleasure craft, where speed and personal convenience are frequently the principle questions involved.

The particular type, make, and kind of engine to instal in any particular commercial craft is almost entirely dependent upon the conditions peculiar to that case, and no general rules can be laid down, nor can any guidance be given until that particular class of craft comes up for special consideration. The same thing applies also to the type, design, and build of the hull, and to the choice of propelling gear. Still, there are certain considerations common to all classes and types of boats, the most important of these being the actual installation. A good motor in a first-class hull may, as a combination, be utterly useless simply on account of faulty installation and negligence in details. Given a good motor and a good hull as a start, the installation—or combination of the two—should be up to the same standard of excellence if the resultant product is to be of any real use.

Installation.

The most important consideration in a commercial vessel must be low running cost. This is largely regulated by the manner in which the installation is carried out. The efficiency of the motor and the power absorbed in propelling the hull a given distance with a given load are variable quantities certainly, but they vary only within fairly close limits, and consequently may be left out of consideration for the present. If the motor comes from a good firm, and the hull from a reputable yard, the amount spent in fuel and other necessaries for the engine will very nearly represent the total cost of running. There is insurance to be considered, and the wages of the hands employed to run the boat, but these are trifling if the mileage covered is great. Loss of time due to breakdowns, repairs and overhauling, will be minimised. In fact, going to the heart of things, the four essentials are safety, economy, reliability and simplicity. Safety is dependent upon the standard of installation, almost irrespective of the nature of the fuel employed; ultimately, when proper legislation comes, a high standard of installation will mean low insurance rates. Economy is a great desideratum, dependent upon the efficiency of the engine, of the transmission of the power—that is to say, installation,—of the propulsion, and of the design of the boat. Reliability is more often a question of installation and accessory details than of a faulty motor. Finally, simplicity directly affects the wages bill; often a boat could be run with a lesser number of hands if the installation were only thoughtfully arranged and the controlling gear properly designed and placed. In a modern petrol boat the motor comes in for a good share of blame, when perhaps it is only the ignition or the fuel supply which may be wrong, both of which are really accessory rather than actually integral with the motor. In such cases the man who carried out the installation is the person to blame. Just as in designing, say, a crankshaft, it is made a good many times stronger than is absolutely necessary; so, in a commercial motor vessel, the standard of excellence of the installation should be considerably higher than is absolutely necessary; a certain margin must always be allowed for the unexpected.

Fuel Tanks.

If the fuel used is of a safe and solid kind, such as coal, coke, anthracite or charcoal, its storage presents problems of no particular difficulty. But in the case of liquid fuel, no matter what its flash-point may be, the design and installation of the tanks, piping and connections is a matter requiring care. For example, a fire once occurred on a paraffin engine-driven vessel through the gradual loosening of a small screw in the vaporiser heating burner. This was caused by the excessive vibrations of the motor, which in turn was due to the boat builder's fault in designing and building the foundation for the motor. The engineer was in some sense to blame, certainly, for not having

gone over the nuts on his engine before starting, but had the foundations been adequate, it is many chances to one that the accident would never have occurred.

The exact position of the main tanks relatively to the engine must be settled separately for each particular case. But in general for the whole system, tanks, piping, joints and connections should be perfectly and absolutely tight, and as a whole, should be tested by filling them with paraffin. It will readily be grasped that hydraulic pressure might drive dirt into leaks, and so stop them up. Paraffin loosens dirt and thus exposes leaks. Petrol is dangerous to use and, moreover, evaporates too quickly to show leaks. Such a test should always be made, and insisted upon, before accepting or making delivery. In the case of a boat for use in rough water, and where the tanks are of any size, or for a pressure-feed system, a test becomes very important. The material to be used for the tanks depends upon opinion. Zinc and galvanised iron are not so good as copper, or mild steel—either plain or with a lining of tin. All joints should be riveted and soldered for longitudinal joints and the ends riveted, tinned over and sweated, or else all joints should be

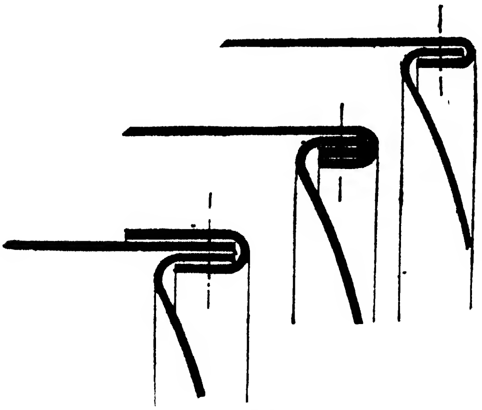


Fig. 1.—End joints for tanks.

electrically welded. There are partisans for each system, but for tanks of any size mild steel with electrically welded joints work out as cheap as anything else. The writer once purchased a pair of such tanks, six feet long by 18in. diameter, with all joints, bungs and unions electrically welded and each tested to 75lb. ab. pressure, for the sum of £8 10s. the pair. They have this advantage also, that the joints are actually stronger than the metal of which the tank is made, and there can never be any possibility of leakage. Indeed, such a tank can be battered all out of shape, and, unless wilfully perforated, will be as tight as ever. On racing boats it is quite permissible to cut down the weight by reducing the scantlings of the fuel reservoirs, but in the generality of commercial motor boats it would be false economy to follow such a precedent. Still, there might perhaps be some valid cause for cutting weight in a commercial boat, and in such a case an excellent type of light-weight container is shown in the illustration (fig. 2). It consists of a thin steel drum pressed out of a solid sheet; a round hammered-out steel plate is slipped in the open end, the projecting end of the shell is then tinned over, riveted through, and sweated. If necessary, such a tank may be obtained with a block-tin lining. In the case of fairly large reservoirs, especially for sea-going boats, perforated baffles should always be fitted to reduce the stresses consequent on the contents swashing about in a seaway. In cylindrical tanks there need be no necessity to rivet these to the shell—this would only increase its potential weakness—they can be slipped in before closing one end. Cylindrical or elliptical section tanks are preferable to cubes or irregular forms made to fit corners, for with a given scantling they are much stronger, and therefore should be used whenever possible.

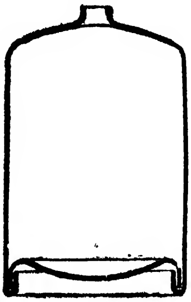


Fig. 2.—Pressed steel barrel tank.

Fuel Pipes.

Nothing but good cold-drawn copper tubing of substantial thickness should be used for conveying the fuel to the motor. No joints should be allowed other than those necessary for coupling the tanks and vaporisers together. Each connection should consist of a single length running from joint to joint along the shortest course compatible with due protection. Expansion joints should be provided to allow for expansion and contraction under varying temperatures or for straining of the hull. A protective covering batten should be run alongside the tube wherever there is any possibility of its becoming damaged, particularly in the engine room or in passage ways, where it

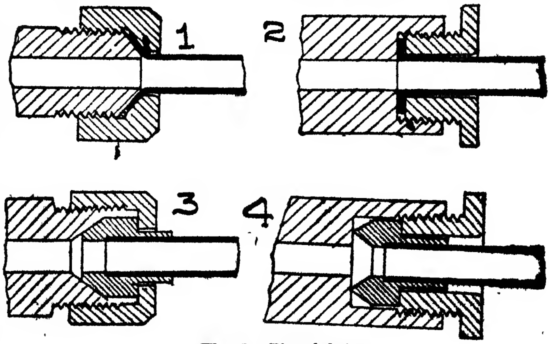


Fig. 3.—Pipe joints.

might suffer from things dropping, or from being stamped upon. All joints used for connecting up the pipes should be of a good pattern. There are four types in common use, as shown (fig. 3). Of these, No. 1 is bad, and should be strictly barred, as the pipe tends to break off where the splay-out begins. No. 2 is only slightly better and is open to the same objection. No. 3 and No. 4—the ground-in cone and knife-edge joints—are both good, and the specification should insist on one or other of these types. All such connections should be brazed on the ends of pipes and not merely sweated on with solder. This should be done before the system is tested. In running the fuel pipes it is as well to see that they run on the opposite side of the boat to the exhaust pipe, no matter what the flash-point of the fuel is. If heat is necessary for the proper vaporisation of the fuel, this will be allowed for by the motor maker in the engine, and all pipes and tanks should be kept away from any source of external heat. Unless the fuel is of a very viscous nature, it should pass through a filter before entering the supply pipe, and the filter should be of a type that admits of easy inspection and cleaning. There are several kinds of filter now on the market. Figs. 4 and 5 illustrate suitable designs.

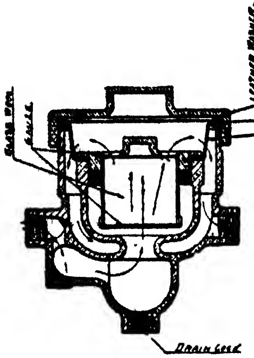


Fig. 4.

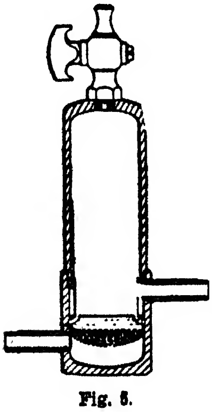


Fig. 5.

Cooling Water System.

The cooling-water circulating system, too, needs more care in design and installation than is usually bestowed upon it in pleasure craft. The main troubles to obviate are: obstructions in the suction piping, and necessity for priming the pump, and both can be obviated by simple means. Generally, the pump supplied with most motors is of the rotary type, and while some of them can lift to a fair height when once agate, they do not seem able to exhaust any but the smallest amount of air from the suction piping. The pump, therefore, should be so placed relatively to the water line that it primes automatically. If it forms an integral part of the engine, and trouble is experienced in this direction, it should be removed and placed in a more suitable position. To remedy troubles arising from obstructions collecting in the suction inlet and piping, the water entering from outside should pass through a filter placed immediately over the inlet orifice, which should not be plugged with gauze, as is usually done. Fig. 6 shows an excellent type of filter; by undoing the cover and removing the cage a stick can be passed right down through the inlet to clear„it when necessary. A fairly large inlet orifice will be less likely to choke than would a smaller one with its outward end fitted with the usual sheet of gauze. Small obstructions can

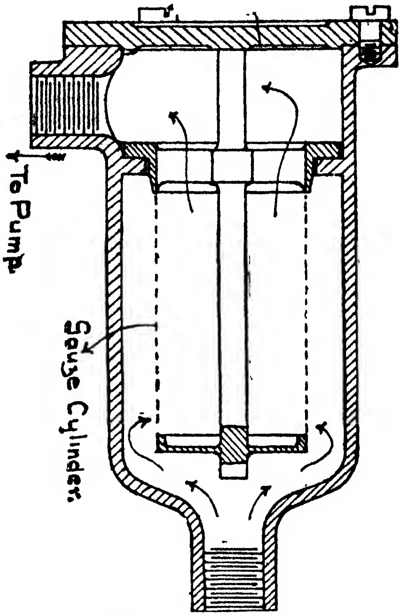


Fig. 6.—Water filter.

pass right through into the filter, and obstacles large enough to choke up the inlet pipe are not likely to come along often. It generally lies with the motor maker to decide the fate of the cooling water after it has passed round the cylinder jackets, and his decision is influenced by the silencing arrangements provided.

If the fuel feeds without interruption to the motor, and if the motor be cooled judiciously and continuously, we have already made two steps towards the perfect boat.

Ignition Systems.

A most important point in connection with the installation of power in a commercial vessel is the ignition system. Faulty installation of this is the prime cause of nine out of every ten breakdowns that occur.

Actually, there is no real reason why electric ignition should not be as reliable as any other

system, and, as stated above, its present general unreliability is largely a question of irrational installation.

Insulation may be defined as tightness against electrical leakage, and, just as in the fuel-feed system, it is the various joints and connections that are most liable to give way and leak. Since electric ignition is, in most cases, a necessary evil on board any motor boat, it should, first of all, be thoroughly well installed and then stringently tested as a whole to a satisfactory electrical pressure. As a general principle magneto ignition, preferably of a good low-tension type, should be installed and used as the regular working system, and whenever a boat is to be used on hard and continued service, a second complete and distinct set should also be fitted as a stand-by; if considered desirable, high-tension coil and battery ignition may be used for this second set, only, in such case, primary batteries of some kind would be preferable perhaps; there are dry batteries now on the market that will remain in good condition when out of use for months at a time.

Wiring and Protection.

If the engine be not in a cabin or an engine-room, special attention must be paid to the wiring. Each wire, whether in the primary or the secondary circuit, should be run in some one of the many conduits now on the market. There is no difficulty in obtaining this conduit tubing, as it is in current use for house and, particularly, workshop wiring. The tubing is sold in suitable lengths, and watertight switches, fuses, junction boxes, elbow and tee-joints can be purchased to complete the running. In this way the greater portion of the electrical system is perfectly protected from damp and wet, and practically immune from breakdown. Batteries and coil should be placed under cover in such a position that no water can ever possibly get to them. If the engine be at all exposed, a shield should be placed over the contact-maker if this be not watertight, so that water will not drip into it. A useful tip in wiring an open launch is to arrange a sharp V bend—downwards—in the run of each wire between any connections or apparatus; any moisture thus collected on the surface of the conduits tends to gravitate and drop off from the lowest point. Wires should never be arranged so that moisture can run down towards any instrument.

In open and cabin boats alike, some mechanical protection should be afforded to the sparking plugs, and the wires connected thereto. There are several protectors on the market—mostly in the States though—that give both electrical and mechanical protection. A sparking plug is generally a delicate thing, and a spanner dropped on it may damage it hopelessly, and what is worse, necessitate stopping the engine while a renewal is made Water and mineral oil are both bad for the insulation of a plug, and the use of protectors will serve admirably to keep the plugs dry and fit. In wiring a cabin launch, wires should never be run under or along the floor. They should rise up from the magneto or coil, be run along the ceiling, and thence downwards to the plugs and other connections on the engine. In engines working with the coil and battery high-tension system of ignition, if provision be only made for one plug per cylinder, each plug might be connected to two ignition systems, each having efficient switches for cutting out.

When all the ignition instruments, wiring, and fitting are installed and connected up, the system as a whole should be tested for insulation resistance in the ordinary way. Most electrical firms possess the instruments necessary for making tests. The minimum number of megohms allowable is difficult to state, since it depends largely on the type of boat and the amount of wiring.

Control Arrangements.

The last point to consider in connection with the installation of commercial vessels in general is the method of grouping and placing the various controls, both of the engine and the boat. In slow-speed heavy-displacement vessels, this question presents problems of little difficulty. Such vessels are generally driven by heavy slow-running engines, working at constant speed when on load, and prevented from racing when free by some form of automatic governor. In most cases of this nature, one lever suffices, whether the propeller is of the reversing type or driven through a reversing gear. The engine looks after itself automatically, varying its power according as the load is put on and thrown off, so the only thing for the steersman to work is the propeller or the reversing gear, as the case may be. In barges, motor tugs, and other vessels of this type, the engine is generally placed well aft, and the steering wheel is aft also; the reversing lever can thus be placed quite close to the steering wheel so that it is within reach of the helmsman. In the case of lighter and faster vessels with variable speed engines the control problem is rather more difficult to solve satisfactorily; two or three control leads may be needed to the engine, in addition to the lever actuating the reverse. Thus, in arranging the installation of a boat, this question must receive due attention from the very first, and the steering platform and position of the engine-room should be so placed relatively to one another as to facilitate the control transmission. The question of position of weights cannot be lost sight of altogether, and possibly a compromise will be necessary. Still, to prevent the necessity for complicated collection of links, rods, and bell cranks, the controlling levers on the bridge should be placed as near as possible to the various things they have to control. For small things such as throttles, spark advance and retard, and governor regulator, Bowden wires answer very well. The writer has installed these for controlling the engines in two boats, and they

have given every satisfaction. Only they must be well protected from wet. They can even be used to control heavier apparatus such as reversing gears and reversible bladed propellers, but in such case the connections both to the apparatus and the control levers must be properly designed and proportioned. Haphazard details are the cause of endless future worry.

Motor Barges.

The two most important considerations in connection with the design of a motor barge are running cost and dimensions suitably proportioned to the waters it will have to do service in. The cost per ton mile of transport must be kept as low as possible, in order to attain a maximum of useful work, and the barge must be of such a size that it will pass handily through the smallest lock in the system over which it runs. There are many such vessels afloat, even in our own waters, which make trips of considerable length, and, when an order is received for a vessel to replace a towed boat of the present type, the supplier should be possessed of proper data concerning the dimensions of the locks through which it must pass. From these the leading dimensions of the vessel can be fixed.

Choice of Fuel.

The choice of fuel is limited rather more than is perhaps the case with certain other types of commercial vessels. While paraffin can be used with every success, it appears fairly certain that suction gas is, possibly, above all others the most suitable fuel for motor-barge work. Weight of plant is of very little importance on board such craft, and there is usually no particular reason for great economy of space, so the extra room necessary for the generator will not count. Petrol need never be thought of for barge work, for it is not only far too expensive a fuel, but also it is too dangerous to be in charge of inexperienced men. The one essential of a barge installation must be simplicity. The whole installation should be of such a type that the average bargee will be able to run it efficiently after a short course of training. This is one of the reasons why many motor barges running on the Continent are fitted with ordinary horizontal oil engines of the standard land type. They are heavy, they are also cumbersome, but, as a set-off, they are cheap in first cost, they are particularly simple, and, most important of all, they are but little liable to breakdown. Certainly it is a peculiar sensation to go down the after end of a big Rheinbarkasse and see there a big land engine stolidly thumping away, but the work is done all the same. Properly installed, this type does not take up very much room, and, as pointed out above, the weight is a matter of little consequence.

The Arrangement of a Continental Barge.

An illustration (fig. 7) is appended showing such a motor installed in a Continental barge. In each case, the motor is fixed in a compartment right away in the stern; immediately forward of this generally comes the captain's quarters, while the crew—if any—are lodged right forward in a sort of fo'c'sle. It will be seen from the illustration that the engine is an ordinary horizontal oil engine driving on to the propeller shaft by means of a belt and bevel wheels. In this case only a single screw is fitted, the after sections of the under-water body being fined off to allow the water free access to the screw. In other cases (fig. 8), two propellers are fitted, well away from the centre line, both of these being driven by one engine. It will be noticed that the screw can be raised and lowered, the object of this device being to secure a full-bodied ship with a maximum of carrying capacity. In deep canals or estuaries the screws are lowered to their full depth, and are raised up when passing through shallow locks or canals of little depth.

Having the engine right aft under the steering platform simplifies the connections between the control levers and apparatus. The helmsman has everything under his own control, and one man suffices to run the boat, except when locking and unlocking— a man is then needed forward to hitch on and cast off warps. Vessels of this type are in current use in Germany, Holland, and Belgium, where the canals and locks are both wider and deeper than is the case here in England, and many of them make lengthy trips down the estuaries of the western coast of Europe. None of them are, of course, sea boats, and even in an estuary they are pretty wet, running as they do with their decks awash. For estuary work, anchors and winches are fitted both fore and aft, and, when bringing up to make a port or a canal entrance, the usual practice is to continue running full speed ahead, and then drop the stern anchor, which acts as a drag.

A modification of this type of boat would certainly have its uses in English waters, but could only be used in estuaries and for short coasting trips, since the dimensions are far too large to allow such a vessel to pass through the general run of British canals. Here our canals are, as a rule, shallower and narrower than is the case abroad; the locks are shorter, too, and thus our canal barges are altogether smaller than those on the Continent. Still, the accepted principles of Continental practice would fit in perfectly well. There are several good motors simple enough to be run by a bargeman with a little sense and training, and there appears little doubt but that horses and canal tugs will be ousted almost completely in a few years.

Speed and Propellers.

Speed on a canal is limited to a great extent by other boats. It is no use having a fast barge, if it will have to wait at a lock for its slower

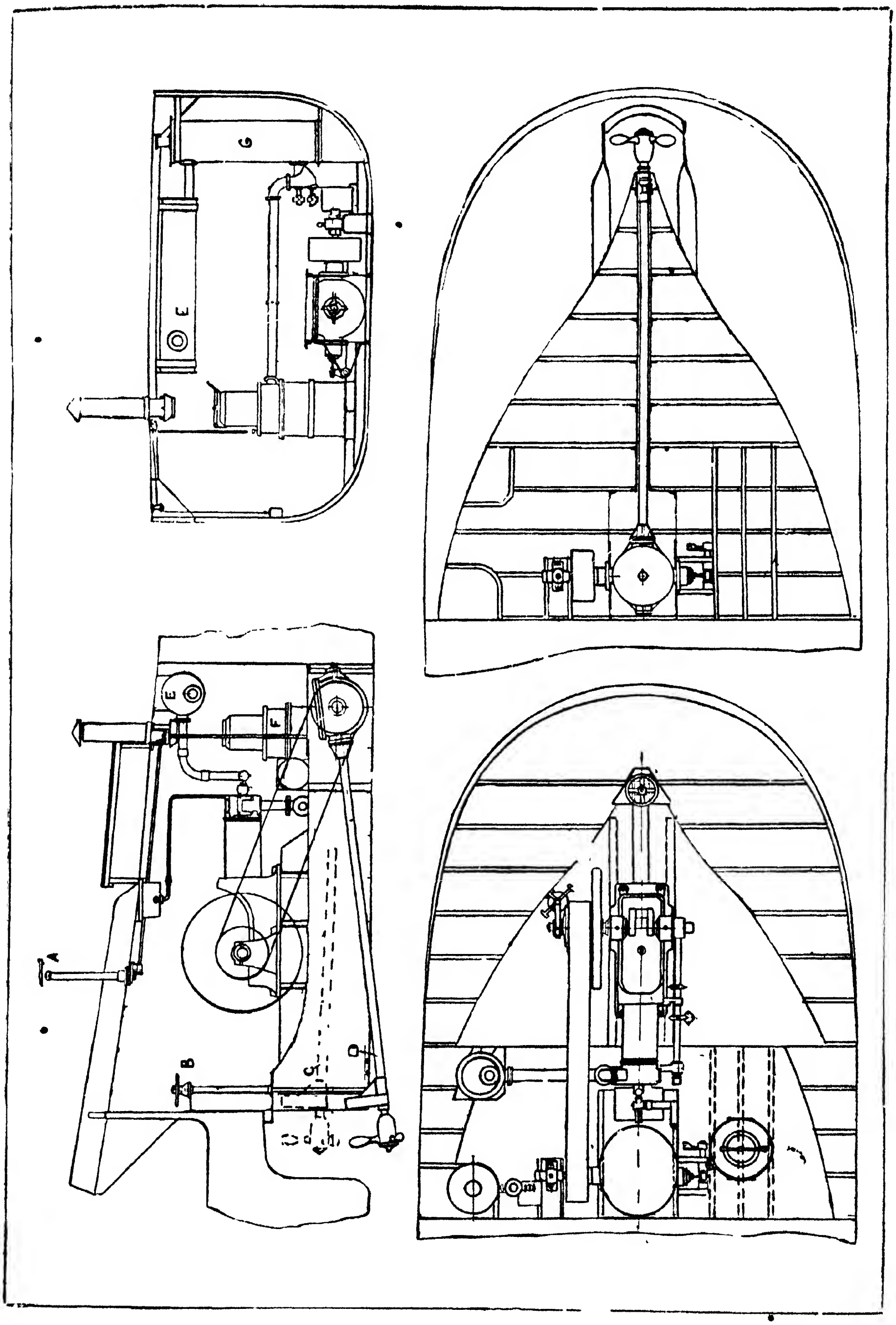


Fig. 7.—Method of installing a suction gas plant and horizontal motor with lifting screw.

A, hand wheel to reverse the propeller. B, hand wheel to raise or lower the propeller. C, highest position of the screw. D, lowest position of the screw. E, producer-gas container. F, producer-gas generator. G, producer-gas scrubber

brethren, and this must be taken into account in fixing the power. In many cases, too, the canal authorities have something to say on the speed question, and it would be wise to consult them early in the proceedings. At a moderate speed, say, somewhere about the speed of boats at present in use, only small powers would be necessary. In considering the installation, the motor can be generally placed right aft, and should be separated from the main hold by a more or less fireproof bulkhead; with a suitable engine—one working at constant speed on load—there will only be the reversing lever to attend to, if the engine has an efficient governor. A constant speed engine almost necessitates the use of a reversible-bladed propeller, which for such work is generally simpler, and needs less expert attention than would a reversing gear. This is particularly the case on a barge for use in both canals and estuaries; a little less pitch can be given in the canals if necessary, and the boat let out a bit more in open water. A friction clutch should always be fitted between the engine and the propeller shaft. Canals are sometimes very shallow at the sides, and it might be necessary to pole out a little before getting under way. For the same reason, particular care should be paid to the water-circulating arrangements, especially in the direction of ease in cleaning out the water intake, should this happen to choke up with mud or floating matter.

In building a new boat, it would be almost advisable to build it of iron, except in cases where wood might cause a considerable reduction in cost. One advantage of an iron boat, especially if it is driven by an engine consuming a liquid hydrocarbon, is that the engine-room can be practically isolated from the remainder of the boat, and so any leakage prevented from draining off into the hold.

There can be no doubt that for these slow-speed, heavy-displacement craft, the internal combustion engine is the best form of propelling agent ever yet devised, and on the score of working economy it can give points to every other system.

A Comparison and a Specification.

It is interesting to compare two very different types of barges. One is "Good Luck," a paraffin-engined boat in actual service on the Sheffield and South Yorkshire Navigation Canal; and the other is a Continental vessel, built and engined by a Belgian firm, and running on the canals of Northern France. "Good Luck" is 60ft. 6in. over-all length, by 15ft. 3in. beam, and 7ft. 6in. depth amidships; she is fitted with a 25h.p. oil motor, which suffices to drive her at a speed of 6m.p.h. The other vessel is iron built, 150ft. long, 20ft. beam, and drawing 5ft. with a cargo of 280 tons on board. She is fitted with a 20h.p. suction gas plant, working with anthracite. The ordinary type of barge in use on English canals is about the same length as "Good Luck," but only about 7ft. beam, the draught being generally 4ft. An extract from the specification of the Continental boat may be of interest: The hull is of 4mm.—3-16in.—plating, the bilge strakes being 5mm.—¼in. Five watertight bulkheads are fitted, dividing the hull up into four compartments, engine-room right aft, two cargo holds, and crew space right forward. The deck is of ¼in. chequer plating, and the coaming of the hold is 13in. high and 3-16in. thick. An elm rubbing strake, 75mm. by 110mm.—3in. by 4⅜in.—with an iron armour strip, 63 by 13mm.—2½in. by ½in.—runs right around the hull. The holds are of the dimensions stipulated by the suppliers, and are floored and sided with 40mm.—1½in.—pine. This boat was specially designed to carry bar iron from an iron works to a bolt-making shop, and the hold is therefore fitted with racks to carry bars of any section securely, and to simplify loading and unloading.

Fuel Consumption.

The consumption of fuel is approximately 400 grammes (.9lb. about) anthracite or 450 grammes (1lb.) coke per h.p. hour in full load, and the consumption over the regular working trip of 33 kilometres (20 miles) is never over 35 kgs. (77lb.) of coke. This is the total amount burnt on the trip, locks and other stoppages being counted in. On this particular vessel there is only one man to run the boat and engine. He goes aboard, oils up and overhauls his engine generally, starts her up, and goes on deck. During the four or five hours' regular run he only descends once, or at the very most twice, to fill up the generator. The lubrication is for the most part entirely automatic, and wherever possible cups are fitted instead of the usual oil holes. The firm owning this boat have another similar vessel, and they work alternately backwards and forwards, one going back while the other comes up with a full load.

Motor Barges in Holland and Belgium.

There is a little fleet of small lighters—they are hardly big enough to call barges—driven by 6h.p. horizontal engines, doing regular tramp service between Amsterdam, Rotterdam, Antwerp, and other Dutch and Belgian towns. They are well-shaped little craft, with finer sections fore and aft than the ordinary run of lighters. They have a small pole mast rigged up forward with a small derrick crane, and a sail can be hoisted in the event of a breakdown occurring. On these vessels, too, there is only one paid man, though his family generally travels with him. These boats are much in the same style as "Good Luck," but they are more shapely and not quite so beamy. Most of them have Van Rennes engines and drive the propeller shaft by friction from the fly-wheel. The astern motion of the propeller is obtained by a countershaft and belt drive.

A Computation of Running Costs.

It might not be without interest were the actual running cost of a certain 100ft. Continental barge computed for the different fuels actually in practical commercial use. The vessel, as built, runs on anthracite burnt in a suction gas producer, and on this fuel its regular full load consumption is 400 grammes—.9lb.—per horse-power hour. On test with coke the consumption was 50 grammes more per horse-power hour—about 1lb. Since the barge runs a 33 kilometre trip on a total consumption of 35kgs. of coke, the equivalent consumption per mile in British units is 3.3lb. With the dead-weight capacity of 125 tons the consumption per ton mile is .027lb. approximately. Were coke at 12s. a ton used, instead of anthracite, the actual cost of fuel per ton mile would be an almost infinitesimal amount. Each barge makes one trip per day, and the skippers' wages are 75 francs (£3) a month. Thus for a month of 24 working trips a total load of 12 by 125 tons is carried—the run back being made light—the consumption over the 24 trips is 35 by 24 = 840kgs. = 1,848lb., say, one ton; this gives allowance for starting up the generator, unexpected stoppages and waste. Consider lubricating oil and small sundries at about 8s. per month, and the actual cost of transporting 1,500 tons of cargo is £4 for fuel, wages, and engine stores. Adding 25 per cent.—a liberal allowance—to this sum for renewals and cost of spare parts we reach £5, which, divided by 1,500, gives the cost of transport per ton per mile as .8d. The depreciation of the vessel is a more difficult matter to arrive at, but plenty of statistics as to the life of such boats could be obtained: it is probable that the engine would have to be renewed long before the boat itself showed signs of old age.

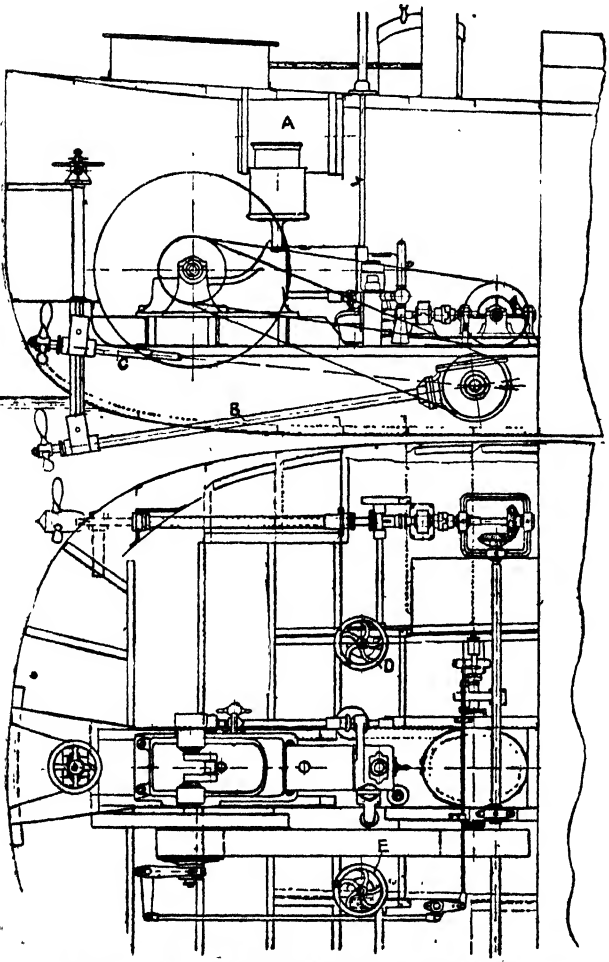


Fig. 8.—Twin screws driven from a horizontal engine.
A, fuel tank. B, lowest position of screws. C, highest position of screws. D, E, reversing wheels.

These figures, it must be remembered, are for a boat working under rather annoying conditions. The two points between which she plies are fairly near together, yet the time required to load and discharge the cargo prevents the boat making more than one trip per diem. Were a similar boat to be used for long-distance transportation the cost of running would drop considerably—the cost per ton mile that is. The figures, too, show another important point; they show how small a proportion the fuel cost bears in comparison with the other numerous expenses entailed and also they point out clearly the necessity for cutting down expenses by reducing the number of hands employed aboard to the lowest practicable limit, rather than by seeking economy by securing the cheapest fuel. In the particular case under consideration the wages bill, although very small, is nearly four times the amount expended on mere fuel. As pointed out before, the number of hands necessary to run the boat depends largely on the skill and experience of the man who designed the installation and the control system.

Depreciation and Fuel Consumption.

Probably in actual practice depreciation would form a heavy item, but it appears rather doubtful whether this should be included in the running expenses. The cost of spares and stores must be so dealt with, naturally, but depreciation items would probably find their proper place in the trading account and not in that dealing with the commercial utility of the fleet.

Were paraffin used to drive this barge about 70 pints would be needed for each

trip; if a petrol engine were installed the quantity would be about the same. Taking paraffin at 4½d. per gallon, and petrol at 9d. per gallon, the cost of fuel per trip would be about 3s. 3d. and 6s. 6d. respectively, as against 4s. in the case of anthracite. The difference is certainly great, but even then, with the dearest fuel, the wages bill is heavy in comparison. Anthracite is a fuel that varies considerably in price according to locality—from 12s. to 25s. per ton—but at its highest price it compares very favourably with paraffin and knocks petrol practically out of the running. Actually, in considering estimates for a motor barge, prospective buyers should be clear in their own minds on this subject of fuel consumption. It is hardly fair to the makers to multiply the full load consumption by the number of hours under way, and at the same time misunderstandings may arise over the supplier's endeavours to estimate the actual cost for fuel over a certain trip.

Motor cargo barge fitted with 24h.p. single-cylinder paraffin motor. Length 55ft. 6in., beam 12ft. 4in. Capacity 20 tons, speed 7 knots.

Possibly the first motor barges at work were built for petroleum companies and fitted with paraffin motors; in some cases ordinary land engines were installed in a compartment astern. Some such vessels have been in regular continuous service for several years already, and in Belgium two such tank barges have been running for a longer time. These vessels come to the companies' dock, and are filled or emptied as the case may be in about two hours. Centrifugal pumps are installed at the receiving end of the trip, and at the charging end the oil is run through a pipe direct from the storage cylinders into the hold. In such case, with an unlimited supply of liquid fuel aboard, it would hardly be policy to install, say, a suction gas engine, except in localities where transport difficulties have enhanced the value of the oil. But abroad, on a good canal system, the tank steamers from the oil fields discharge into the store, and from this the oil is delivered to a number of centres, more or less far away, by motor-driven tank barges.

Small Lighters and Auxiliary Barges.

Before leaving the question of barges, there are two types of vessel that seem to offer possibilities, small fast lighters and auxiliary sailing barges. The Deutsche Ost-Afrika Linie has a Daimler-engined lighter at a station on the East Coast of Africa, and this boat goes out to collect merchandise from the Company's steamers lying off the coast. Such boats are really barges, yet they hardly trespass on the domain of the larger and slower vessels for inland and estuary work. There are many ports in the world where large steamers cannot enter and dock, or bring up to a quay, and a well-organised service of such power-driven lighters should prove a little gold mine to the organisers. At home on inland waters, or in estuaries, they might be profitably worked where a passenger service would not pay, for there are many localities where transport by water would work out cheaper than carrying by road.

Motor Tugs.

In all probability there will be a large number of motor tugs afloat before long. There are already a good many abroad, principally in Germany and Holland, where they are doing good and continuous service. It is rather early yet, perhaps, to think of building motor tugs as powerful as the ocean-going steam tugs one sees at large shipping centres, but there is plenty of work that smaller vessels could do—boats, say, from 30ft. to 80ft., with engines of from 10h.p. up to 150h.p. Many of the conditions applying to barges hold good in the case of tugs. The engines should be solid, simple, preferably slow-running affairs requiring a minimum of renewals, repairs, and attention. The fuel problem is not, in general, so difficult of solution as in certain other types of craft. Petrol may be left out of the question altogether; except, perhaps, in one or two very special cases it is too expensive a fuel for ordinary use, besides being dangerous no matter how carefully the installation is carried out. The crew usually found on tugs are inexperienced in the ways of motors, and might as a consequence be careless.

The hull of a tug-boat is not a thing to put in the hands of a mere maker of motors. They have to undergo severe strains when hauling, particularly so in a heavy sea, and should therefore be designed and adequately built by some firm which has had plenty of experience in this line. It is not an average designer's job to design a tug, and, in general, it would be better to order hull and motor separately and bring about an understanding between builder and maker to come to some mutual arrangement for the installation. The builders, too, will be able to foretell the power to a nicety from their past experience, and this power cannot be calculated from an ordinary formula. Generally the ordinary tug-boat running alone at her hardest makes some fearsome waves because her engines drive the hull too hard; when towing and going at her normal speed the waves decrease immensely, and the boat runs cleaner. The average towing load and the style of lighter to be towed should be stated when getting estimates or ordering a tug, for the power to be installed is almost entirely dependent on these two factors, and the shape and dimensions of the tug itself go for very little.

The Asiatic Petroleum Co.'s motor tender and tug at Port Said.

Generally speaking, paraffin and suction gas are the best fuels for use on such tug-boats, on account of the economy and simplicity of the engines. The control arrangements should be collected on the steering platform to be all under the skipper's hands as he steers, and thus allow him to have perfect and instant control over the boat at all times. It would not be a bad idea, in certain cases, to instal a reversible-bladed propeller. When towing, the boat could run with the blades set at full pitch, and when running light could be run at a good speed with rather less pitch, the engines would govern and decrease the consumption.

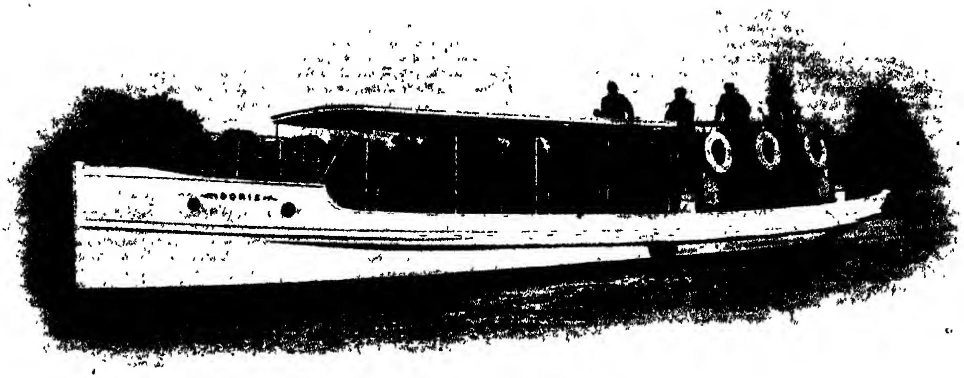
Advantages of Motor Tugs.

In many cases internal combustion motors would present considerable advantages over steam engines for this class of work. The boats could be got under way in much shorter time than that required to raise a sufficient head of steam in the boilers, and at times this fact might be of the greatest importance. Again, there are many steam tugs now on which a head of steam is continually kept up, entailing considerable expense for coal to the owners. With internal combustion engines fitted this would never be necessary, as were a tug wanted to get under way at unexpected hours the engine could be arranged to start up on a small quantity of petrol, and thus be available for service within a few minutes if necessary. There are steam tugs in many parts which lie in waiting for a call, and which could be fitted with internal combustion engines with great advantage, if the owners could be brought to realise the saving it would be, and how the dividends would increase as a consequence.

Service Launches.

There are now a number of motor launches afloat, chiefly abroad unfortunately, which are of the nature of a combination of tug and service launch. Several steamship companies own such boats, which are useful in conveying passengers' goods and orders from the shore to ships lying outside, and which are fitted with engines powerful enough to enable them to tow a fair load at a decent speed when necessary. On the score of economy, these boats again can give points to steam. The exact time of arrival of a liner can never be fixed to a few hours, and this means, with a steamboat, keeping a head of steam for perhaps an indefinite time. A motor-driven service launch can be got under way once the liner is sighted or signalled, and, as in the case of a "free lance" tug, save her owners a large amount yearly. Such boats—half tug, half launch—would find considerable favour in several colonies.

Service launches are the commercial equivalent of the ordinary pleasure launch, and as they



"Doris," a 60ft. passenger boat in use on the Norfolk Broads. She is fitted with a 20h.p. motor and is licensed to carry 100 passengers.

vary greatly in type and dimensions they must be dismissed without further consideration than that the installation must be carried out in a thoroughly efficient manner, and that the motor and the fuel used must be chosen with due consideration to the work the boat will have to perform and the locality where her work will be. If these problems are solved, first of all, according to the principles pointed out in earlier sections of this article, the boat will be at least suitable for her work, and, given good workmanship and installation combined with subsequent careful handling, she should give satisfaction to her owners.

Colonial Service Craft.

It is obviously impossible in an article of this nature to consider the various types of craft particularly adapted to colonial service in anything like an exhaustive manner; but, at the same time, there is greater scope for giving certain broadly general directions than exists in the case of vessels destined for home service. Considering the fuel question first of all; in temperate regions, where the climatic conditions are much the same as those here at home, the one point regulating the choice of the working fuel is convenience, or, to put it rather more correctly, commercial efficiency. In such climates, too, the installation of power and the general design of the craft do not call for any extraordinary regulations other than those which local conditions may impose as necessary. It is in tropical and semi-tropical climates that special precautions are necessary. It is fairly obvious that there petrol does not show to the best advantage, and that for two reasons; its cost would be high before it could be freighted and carried to the stores, and again because a fuel of such low flash-point would not be suitable for use in so warm a climate and—possibly—in inexperienced hands.

There is plenty of work waiting for the motor launch on the great rivers of Africa and South America, and, now that makers know the particular kind of craft suited for this work, there is already the making of a brisk trade. Unfortunately, the users and the suppliers of craft are so far distant one from the other that it is often a matter of difficulty for the one to make his wants perfectly clear and for the other to realise exactly the type of craft needed for the work to be done.

While there are many colonies where petrol and paraffin can be easily obtained, it seems fairly certain that, elsewhere, the suction gas producer and engine is the power plant par excellence for commercial work, as far as internal-combustion motors are concerned.

Simplicity Essential.

In choosing an engine for colonial service, when the fuel question has been settled, the one point to outweigh all others is simplicity and consequent small number of working parts. All other things being equal, the choice must fall on the simplest motor; an engine with a multiplicity of working parts is not suitable for work so far from its place of manufacture, and should, in consequence, be passed over in favour of something simpler and more robust. Strength in detail parts is another point that must be carefully looked to; no fine watchmaker class of work should be admitted, unless a small cargo of spares is to be carried. If anything goes that cannot be replaced from stock it means that the

boat will have to be laid up while a new piece is obtained from the manufacturer, which may mean anything up to six months before it can be delivered and fitted.

It is obviously unsuitable to deliver a paraffin engine, say, with electric ignition of the usual coil and battery type to a place where electric current is not available, and where a primary battery or power-driven charging set would have to be installed. Colonials are notoriously handy men, but accumulators need handling carefully and with due knowledge rather than handily. In such cases, a simple type of magneto should be fitted, preferably in duplicate. And this, on the principle that apart from fuel, lubricating oil, and the circulating water, no other supplies should ever be needed to keep the engine running. The lubrication should be arranged that all important frictional surfaces receive automatically their due and proper share of oil. In fact, generally the whole installation should be so arranged that once the engine is started and under way, no attention should be necessary until the time comes to shut it down. In two words, the plant must be automatic and foolproof.

Estimated Running Costs and the Choice of a Motor.

It is a very difficult matter to obtain a correct idea of the running cost of a prospective craft. It is, of course, very simple for a maker, or anyone else, to state that the engine will consume, say, eight-tenths of a pint of paraffin per horse-power hour, and then proceed to assume the number of hours the boat will have to run at full load, multiply that figure by the horse-power and this product by the consumption per horse power hour. Unfortunately, the result so obtained does not represent anything like the true cost of running the vessel. This is made up of several expenses. There is first of all the cost of the fuel; to this must be added the expenses entailed in providing lubricating oil, engine stores and spare parts, the cost of having the engine thoroughly overhauled and tuned up once or twice in the year, the renewal of parts liable to wear, the wages and sundry expenses of the hands employed in running the boat, the depreciation of the vessel herself, and—a not unimportant factor—the time lost in breakdowns and derangements of the driving gear.

In this formidable list of contributory expenses it can be seen that the cost of fuel plays rather a minor part in many cases, particularly so in the case of a low-powered, slow-speed vessel, such as a barge, for instance. All these different outlets for the owner's money must be considered in planning a boat for certain clearly defined service, and in the preliminary consideration they should be so balanced and adjusted as to secure a maximum commercial return for the money spent in running the craft. Take the case of a ferry boat, for instance, to ply for service between two points only a short distance apart. Here the relation between the time occupied in bringing up and getting under way is of infinitely greater moment than the actual time occupied in running from point to point. Hence it would be decidedly injudicious in such a case to instal high-powered machinery in order to secure a slight increase in speed, when perhaps half that power would increase the boat's earning capacity. In the case of a canal barge, for instance, plying between certain fixed points it is again obviously useless to instal ultra high-powered machinery to gain a mile per hour or so more speed, when the conditions of service preclude the boat making more than one or two short stages per day.

A balance should always be struck between expenses and earning capacity, as represented by the useful work the boat does. This is a point that, like many others in connection with the same subject, cannot be treated in such a general manner as to cover all cases, for each particular type of craft. Certain broad generalities can be laid down, but even then each and every particular case demands separate attention based entirely on the different conditions of service obtaining.

Items of Running Expense.

It might be as well, at this juncture, to consider in detail the items which go to make up running cost. Depreciation has been a rather serious consideration in motor work, and, roughly, may be set down as proportional to the working speed of the plant. It is obviously greater in a boat of very high speed—one of our modern racers, for example—than it is in a slow-speed barge fitted with heavy, slow-running engines, the general wear and tear and the stresses on the working parts being comparatively small in the latter class. The personal element also figures largely in this question, a careful engineer and a thoughtful skipper will help greatly to diminish this factor. Careful overhaul at suitably spaced intervals will also help to lessen depreciation, and, in addition, will also reduce liability to breakdown. A good motor maker or hull builder will always give advice on this important point, which, if the user is wise, he will carry out. Good ships have been lost before now for want of overhaul, and when such is the case the owner can blame no one but himself.

Wages.

In most cases, the wages bill is the heaviest item on the expenses sheet; an item, too, that very often could be reduced by suitably planning the boat beforehand. Wages are also to a certain extent proportional to the speed of the machinery, for generally most of the heavy, slow-running commercial engines now built need attention only at rare intervals. There are barges now running in Continental waters on which

A Dutch motor barge.

only one man is employed. He first of all starts up his engine and sees that all is right, he then goes on deck and, with the control levers next his hand at the steering wheel, can start, stop, and regulate his speed while steering. It is only fair to remark, at the same time, that the unpaid help of the bargee's family can always be pressed into service to throw a warp or take a hitch with it round a mooring post, or even, if necessity arises, to steer. The fact, however, remains unaltered that such boats can be worked single-handed, and this is a point to strive after in designing. If the boat can be handled by one man, two men can do it in comfort, and in case of emergency the owner knows that his boat need not stop running if there be a man short.

Expense of Fuel.

Locality has a very important bearing on the question of expense. It would raise running cost were a petrol motor used, say, in a colony where that fuel would have to be imported specially. In a coal-producing district, again, it might be considerably cheaper to use coal in some way or other, just as for local service near oil fields a paraffin motor would most probably work out cheaper than even suction gas in its most economical form, although the mere consumption, by volume or by weight, might be considerably greater. It is on this point that many people go astray. Low consumption does not necessarily mean low fuel expense. A suction gas plant under favourable conditions can give points and a beating to steam, but there are cases—though, possibly, they are very few—when it might cost more. In fact, the very first consideration in thinking of a commercial motor vessel should always be "What is the staple fuel of the district?" If it should happen that two or three fuels are equally available, the choice is then governed by relative cost and relative consumption. It is pretty safe to state that in ninety-nine cases out of a hundred there will always be one particular fuel which will work out cheapest for the particular power to be installed.

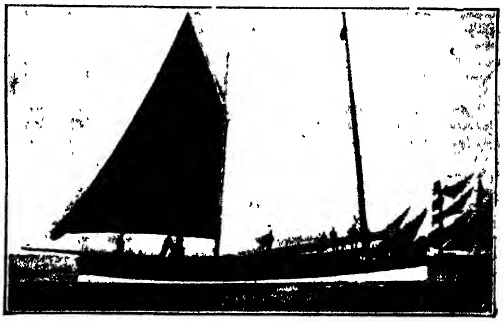
Comparative Consumption with Various Fuels.

The question of the comparative consumption of the different classes of fuel, calculated to a horse-power hour basis, is a rather delicate one to discuss, not so much perhaps in distinguishing between good performances and bad ones as in the fact that few really reliable data are obtainable on the subject. In the case of a service launch used on a canal, when the boat is in a lock, the consumption drops considerably, even if the engine is not shut down. In such case it would be obviously unfair to divide the total consumption by the number of hours the engine is run, for this would give a figure possibly a great deal lower than the actual consumption at normal full load, which is the figure on which instructive comparison must be based. From a mass of figures collected by the writer, average consumption values have been struck, these are given on the assumption that the engine is working under proper conditions and at its most efficient load. For petrol and paraffin the figures are practically the same, .9 pint per horse-power hour; in a fairly good engine the consumption rarely exceeds one pint; while .73 is the lowest figure the writer has met with, and this was in a petrol engine. For alcohol the consumption is nearly double, if the alcohol is fairly pure. If it contains an admixture of benzol, the consumption decreases till at 50 per cent. it almost equals petrol. For suction gas driven engines the average consumptions are for coal $1\frac{1}{4}$lb. to $1\frac{1}{2}$lb. per horse-power hour, for coke $1\frac{1}{2}$lb., and for anthracite 1lb. and under.

The figures naturally vary greatly, and the above can only be regarded as fair average values. Many individual engines of the types considered will consume less, and some may consume more. In actual practice the fact that variable speed engines vary their power according to running conditions will have an effect on the consumption for the total horse-power.

Oil and Stores.

The expenses for lubricating oil and general engine stores depends rather on the engineer than on the engine. Some men are notoriously wasteful in these matters, and others very economical. Here, again, if the owner is not an expert the advice of the engine maker will come in useful, and any hint he gives should



"Pioneer," Scottish motor fishing boat with 25h.p. motor. Speed five knots.

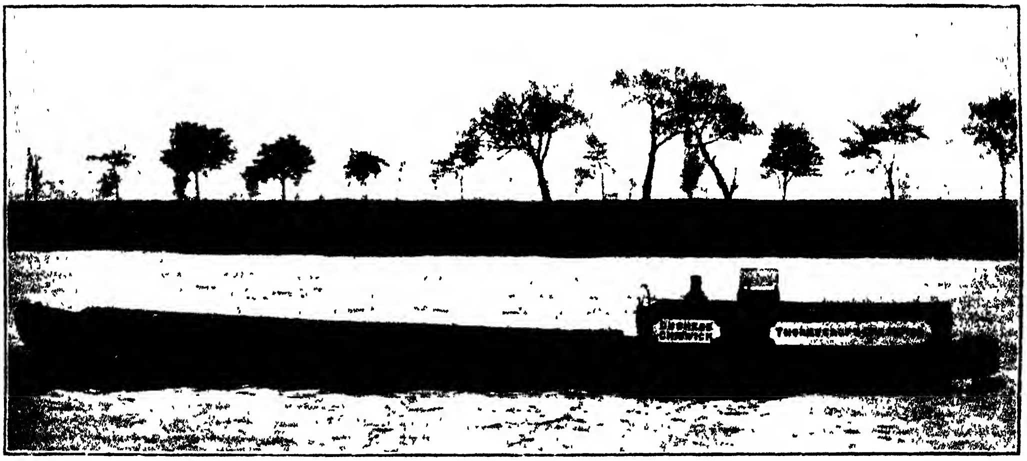
always be carried out. Indeed, the lubrication should always be taken out of the engineer's hands by fitting proper mechanical and central feed lubricators to all working parts needing them. These can all be adjusted during the trial runs so that each part receives its due and proper share of oil.

Spare Parts.

The supply of spare parts is more difficult to consider. Sufficient spares should always be carried aboard each boat, while at the same time undue extravagance should be checked. One case in point. The owner of a certain motor yacht found himself continually paying bills for new valves. He remonstrated with the engine makers, who investigated the matter and found that the man in charge was too lazy to grind them in, but preferred to lose pitted valves over the side and put in fresh ones, which needed little or no grinding to fit tight. With slow-running engines it will generally be found that all the parts have been designed for their work with a more generous factor of safety than is usual with automobile engines, and it will thus not be necessary to carry such a large store of spares as many would advise. It must also be remembered that if an unskilled man is in charge of the engine-room, he will be unable to effect any but the very simplest repairs. It might be advisable to let him take more parts than he could make use of, because, if he can land, it will generally be possible to secure the services of a blacksmith, whose work is seldom to be despised, especially as in the country he will generally be found as good a man at a mechanic's job as he is at his own. In connection with the spares problem, there is one golden rule: the motor purchased should be of such a type that breakdowns shall not occur. A commercial motor is not fit for work if it must be treated as a delicate child, and strength in construction should always be considered a *sine quâ non*.

Relation Between Cost and Return.

These are all points that must be considered carefully and beforehand. There can only be one combination that will do the work required with a maximum of economy. But the relation between work done and running cost must always be looked at in a proper light. For instance, in a barge the question is: What will it cost to carry a certain load, in pence, per ton-mile? In a ferry boat or passenger vessel the cost per average trip must be considered in relation to the average takings per trip. By first of all looking at things in this purely commercial light the prospective owner can give suppliers a clearer idea of his wants. If, say, steam barges are to be replaced with vessels driven by internal combustion motors, the owner should know what his steam fleet brings him in; then he can compare estimates for the alterations and place his orders accordingly. In replacing sailing vessels or towed vessels by motor craft, it must first of all be seen whether the new vessels will do better work for the same cost. This sounds rather obvious, perhaps, but experience in the ways of people ordering boats shows that in many cases they have no very clear idea of the conditions under which they have to perform. If a man is in such a pitiable plight, he can at least state roundly what it costs him to do certain work, and invite motor-boat builders to come along and better it.



An English canal barge fitted with an experimental suction gas motor of 30h.p. Loaded with 10½ tons of cargo and towing a "butty" carrying 23 tons, her speed is about four miles per hour on a consumption of 30 lbs. of fuel (anthracite) per hour.

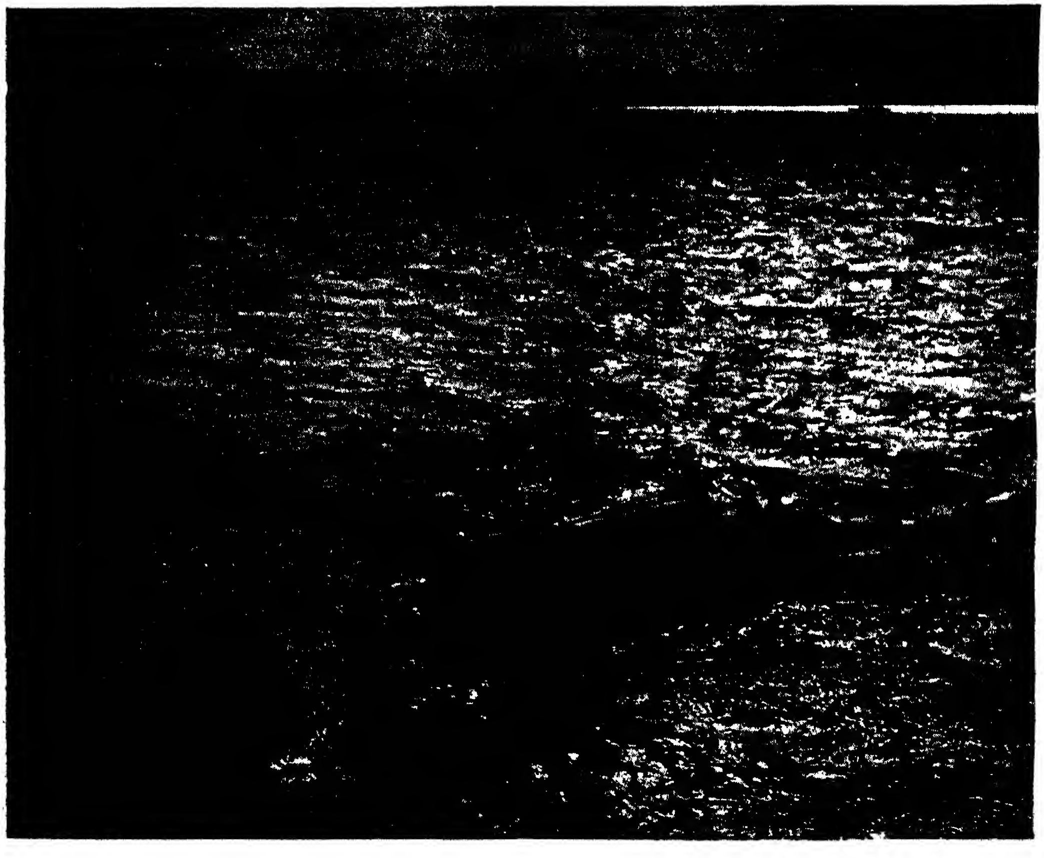
The Motorman Question.

The question of handling has never, apparently, been quite fully realised. There exists an opinion that the services of a trained engineer are indispensable to continually nurse the motor into giving its best output. In the case of commercial vessels any such impression is entirely erroneous. When the crew of a boat consists of two men or more, one should be told off to take charge of the engine. There is no necessity for him to be any kind of an engineer; engineers are not over-handy on a boat out of the engine-room, and in nearly every case it will be found vastly better to get hold of a fairly intelligent sailor man and educate him up to the motor. This is not a difficult matter; the main thing is to get him to understand how it works—usually a simple matter—and insist on his looking after it in a methodical manner. He must be impressed with the fact that the more care and attention he gives his engine when not running the less subsequent trouble he will experience.

The writer has had experience with several marine motormen with different types of motor in their charge, and for all-round handiness it is his experience that the seaman beats the rest. In a sea-going boat, rough weather does not affect him, and in nasty weather he is always fit to look after his engine or lend a hand on deck if necessary. At home, such a man could receive his training from a man sent by the motor makers; in a colony he will have to worry out his own mechanical salvation from his own inborn common sense and any particular instructions with which the manufacturers will trouble to supply him.

Undoubtedly this motorman question is a difficulty, and has been responsible for a deal of unpleasant trouble up to now, but if owners would see that their man is first of all fairly intelligent, and then, that he carries out the makers' instructions properly and to the letter, there ought not to be much trouble with the average commercial engine

The illustrations throughout this section are introduced for the purpose of showing the many varied uses to which the motor engine has been put in commercial craft. In many cases more modern examples of the various types are in existence, but for the purpose it has not been considered necessary to alter them.



THE LIGHTING OF MOTOR YACHTS AND LAUNCHES.

Until the advent of the motor boat the lighting arrangements on board most small yachts was usually of a primitive description. Candles and paraffin held the field against more modern kinds of illuminants. Steam yachts were, and are generally, lit by electricity, it being a simple matter to instal a dynamo set where steam is already available for driving the main engines. Sailing yachts of any size are lit with oil of some kind, as a rule; one or two American boats —notably Mr. Plant's schooner "Ingomar"— had acetylene installations, while a few, but only a very few, had electric light, with, in some cases, a dynamo driven direct off a petrol or paraffin motor.

If a cabin boat is avowedly built for a day craft there is no necessity to worry much about the lighting arrangements, beyond fixing up two or three gimballed candle holders. If the boat does get belated by any chance these will furnish all the light required. But in a bonâ-fide cruiser of a certain size for regular work, some rather more adequate arrangements should be considered. There is plenty of choice; one can take a pick from candles, vegetable oil, cera wax, alcohol, paraffin, compressed gas, acetylene, electric light. The choice must be governed by considerations of personal preference, locality and the service the boat will be called upon to perform. Candles in gimballed holders should always be installed; they are safe, are unaffected by conditions that might put other illuminants out of order, and are a perfect stand-by in case of trouble. Further, no matter what the main illuminant may be, a set of paraffin riding and running-lights and binnacle lamps should always be carried. Economy in purchasing these is generally ill-directed. It is better to pay a good price and get a good set of lamps; it will pay in the long run, for when running at night one's boat and one's life are often dependent on the lamps. Nothing is more dangerous than a lamp that will not burn in a strong wind, or when the boat is swishing about in a sea-way. This is especially the case with the riding-lamp, which should be of the windproof kind, in which a conical inner glass funnel affords increased protection to the flame.

Cabin Lighting.

Returning to the question of cabin lighting, colza oil is generally a nuisance. It entails scrupulous cleanliness of lamps and constant attention, and should not be employed if its use can possibly be avoided. In tropical climates, where mineral oil might be dangerous or not easily procuroble, colza oil has advantages, but cera wax would be even better. This is a solid illuminant and is in extended use on ships making runs to tropical parts. As it is solid it can be carried easily, and presents no danger in high temperature. As a set-off, however, it is generally only procurable at large ports, and must be burned in specially constructed lamps. The lighting-up takes a little time, as the wax has to be cut up and melted before the lamp can be lit.

Alcohol.

Alcohol is in use for the lamps on a few boats abroad, and as an illuminant is excellent. It burns steadily, and with a clear white flame; but here, again, a special type of lamp must be used, preferably one with a burner and mantle akin to the ordinary incandescent gas burner. Such a lamp is all that could be desired, but alcohol is a fuel requiring certain precautions, and, unless for special reasons, an owner would do better to instal something else.

Paraffin.

Paraffin is, and always has been, the favourite illuminant on small yachts, but the lamps used must be of proper design and construction, and receive more care than the average Corinthian generally bestows upon them. Good cabin lamps can be bought at any reputable yacht stores, and should always be slung in gimbals and have all-metal reservoirs. A glass or porcelain reservoir might be all right, but in a heavy sea something might break adrift and smash it, and it is always well to be on the safe side. Lamps must always be kept scrupulously clean, no matter what they burn. Cleaning them should be as much a matter of course as swabbing decks or wiping down the engine. Given good lamps at the outset, with a constant supply of good oil and perfect cleanliness, they should never give trouble. The writer once installed a lamp of the kind known as a Student's Reading Lamp in the cabin of a 50ft. launch; the weighted base, carrying the rod on which the container and burner slid, was screwed up to the ceiling, and the height of the lamp could be adjusted by sliding it up or down the rod and clamping it. Although it was put up only for temporary use for a canal trip, it worked

perfectly well in slightly rough water, but whether it would have kept alight in a heavy sea is another matter. Still, for a calm-water boat such a lamp has several advantages.

Gas.

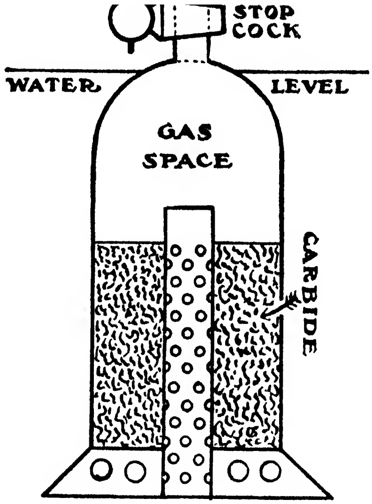
Gaseous illuminants are coming into favour nowadays, probably on account of the great improvements made in recent years. In the case of boats engined with paraffin motors it is generally desirable to avoid a complexity of fuels, and use paraffin for lighting. When something better than the ordinary paraffin lamp is wanted, a Washington or Kitson system could be installed. This is a modification of the "roarers" so much in evidence in a London fog, or when night work is being done in the roads. A reservoir contains the paraffin, which is delivered to the burners by air pressure raised by a hand-pump. Any number of burners may be fitted up, each being connected to the reservoir by fine-bore piping. The burners are fitted with incandescent mantles, and need preliminary heating; though this entails very little time and trouble, and is more than compensated for by the clean white light obtained. Since pitching and rolling cannot possibly have any effect on the light, it is almost the ideal for sea-going craft. Once the pressure is pumped up in a suitable size of reservoir the lamps need no attention for hours, and the whole installation is not prohibitive in prime cost. In a fair-sized boat the reservoir might be placed in the engine-room under the engineer's charge, and pipes be led away from it to the different burners.

Acetylene Gas.

There seems no reason why acetylene should not be used for lighting boats more often than it is. It is in general use on cars, and there are plenty of well-designed and safe generators on the market to choose from. There are already a few boats—chiefly American—with acetylene installations on board, but as there are only one or two firms who specialise in this line, the owner has generally to work out a scheme for himself, and get it fitted up under his own supervision. No matter how many, or how few, the lights, a central generator should feed them all; separate ones only mean trouble and increased danger. The generator should always be placed outside. Under suitable protection from wind and weather it will not come to any harm, nor can it cause any—which is more important. From it a main pipe can be run through the boat, and branches taken off when required, or, as might be preferable, each burner might have its own connection direct to the generator, with a stop-cock at each end.

An excellent generator for acetylene gas lighting has recently been devised, which, for cleanliness, simplicity, and efficiency, has much to recommend it. The system is of special interest in being particularly adaptable to small boats, and on account of the cleanliness of the generator and added brilliance of the light obtainable from acetylene it should prove a boon, especially when cruising.

The apparatus consists of a simple cylinder with a slightly enlarged base to give stability.

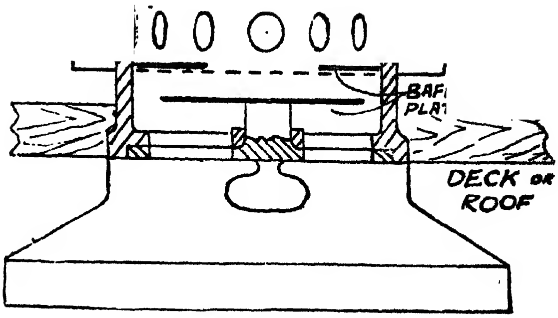


The top is closed by a stop-cock with nozzle for attaching a rubber tube connecting to the gas delivery pipe. A perforated pipe is screwed into the bottom of the cylinder, which is arranged to take out readily for cleaning purposes. For use the cylinder is simply filled about two-thirds full of carbide, leaving a gas space in its upper portion, and the whole apparatus is then plunged in a bucket of water, the bucket being then placed upon the deck or other well-ventilated position. The working of the apparatus is that water enters the central tube at its lower end, and reaches the carbide through the perforations, so that there is always a pressure of gas in the cylinder equal to the head of water from the top of the cylinder to the bottom of the tube. As soon as this pressure is exceeded, the pressure of gas drives the water out of the tube, and so prevents a further quantity of acetylene being generated, until the pressure falls to its normal figure. These generators can either be had in a substantial form, intended for recharging, or simply as cartridges, fitted with caps at the bottom, which have to be broken when required. "Dissolved acetylene" is an excellent alternative that does away with all generator difficulties.

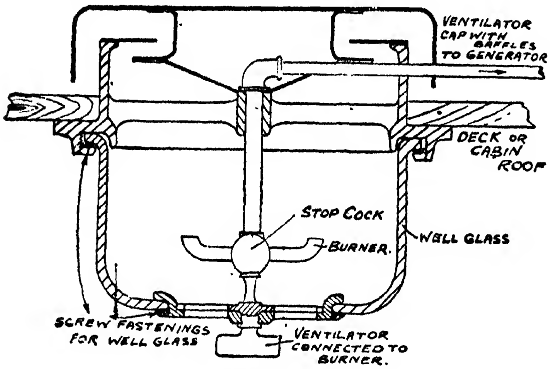
Ventilation.

Since any light gives out a certain amount of heat—and smoke, too, if the combustion is not perfect—a smoke-catcher should always be hung above it, and in the case of acetylene some protected ventilation

to carry off any fumes to the outside. The accompanying illustration shows a type of burner for a small auxiliary yacht. Two acetylene burners are fed by the vertical centre support, which leads upwards through the roof to the deck. The pipe leading to the generator is right outside the cabin, as also is the generator. There can thus be no danger from leaky joints. A well-glass surrounds the burners —of which there are two or three, in order that no shadows may be cast—with a ventilator at the bottom. Above, a protected ventilator is fitted to allow any fumes to escape. The ventilator is connected to the central stop-cock, and both open and shut together. Thus, when the burners are alight the draught carries the heat and fumes up and out, and when extinguished any fumes can go no other way, since the act of turning out the light closes the bottom ventilator at the same time.



Ventilator for any type of burner.

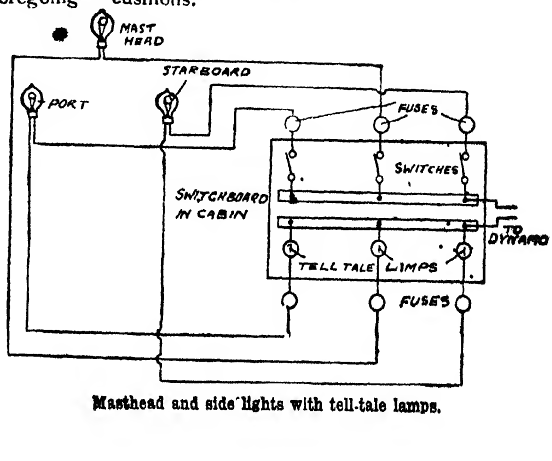


A safety acetylene burner.

Electric Light.

But though each and all of the foregoing systems have their peculiar advantages, electric light seems, above all others perhaps, particularly adapted for use on motor yachts. The motor can be started and stopped so easily that it becomes a very simple matter to charge up a set of accumulators during off hours. The size of the dynamo installed of course depends upon the total candle-power required. As a rough guide, one horse power will suffice to light from 10 to 12 16-candle power lamps, and a proportionate number of more or less powerful ones. If only incandescent lamps are used, the voltage—the electrical equivalent of pressure—may be settled in an arbitrary manner, but if an arc-light projector is installed, it cannot be lower than 60 volts.

Care should be taken that the wiring is properly and efficiently carried out by a competent man; it will pay in the long run. Boat work is hard on electrical stuff, and if the wiring is not up to standard, the insulation may lower badly and cause a deal of trouble. In a boat of any size the work should be put at once into the hands of a competent firm which has had experience in ship lighting. In a small craft this is no less essential, and unless the owner is a practical man he should be very careful if he decides to carry out the installation himself. The accumulators must be thoroughly protected from damp, and, to protect the surroundings, should be placed in a special locker with a lead lining, well soldered or burnt down the sides and round the bottom. In very small craft preference should be given to a type of cell with a semi-solid or gelatinous electrolyte. Acid in a liquid form may creep or spill and damage all surrounding textile matter, such as carpets or cushions.



Masthead and side lights with tell-tale lamps.

Electric light can be fitted to the side and masthead lamps better than any other illuminant except oil, but in doing so all wires leading outside should be of the twin variety, lead covered and connected up to watertight switches, fuses and junction boxes. Each lamp should be fitted with two globes in parallel, so that if the filament breaks in one the light in the other will remain on. It will be strange indeed if the filaments of both should go within a few hours of each other. As a further precaution two lower voltage globes can be used in the lamps and connected in series with a tell-tale lamp placed in the engine room or main cabin. If a lamp should go, the owner is made aware of this by the extinguishing of the corresponding tell-tale. To simplify matters double filament lamps might be used in the side and masthead lamps instead of two single filament globes.

A wiring diagram for masthead and side lights, with their corresponding tell-tale lamps, is given on the previous page.

Finally, it is worth while repeating the advice already given to have candles or oil-lamps—candles for choice perhaps—as a stand-by, and always to carry a complete set of good paraffin side and masthead lights, as well as a spare binnacle lamp. The sea is essentially the domain of the unforeseen, and bright lights at night are a necessity to existence afloat.

See Board of Trade Regulations for requirements as to Navigation Lights.

Upper deck of a typical American motor yacht.

HINTS FOR CRUISING.

The following chapter embodies some notes for the information of the motor yachtsman who is preparing to start on an initial cruise; many of the hints also apply to camping. Further information on several details will be found under the several heads in other chapters.

Before starting on a sea cruise of any considerable length, one cannot devote too much careful thought to the preparations. The first matter for consideration is the amount of fuel required. This will, as a rule, differ very greatly from the ordinary consumption per mile in smooth waters. Consequently, if laying in stores for an extended cruise, first ascertain as accurately as possible the average fuel consumption of the motor per hour at full power and the speed of the boat. Then, by dividing the consumption per hour by the number of miles per hour, we should have the consumption per mile under favourable conditions. This amount, multiplied by at least twice the number of miles from port to port, gives the quantity. Even that is not too safe an estimate, and if there is sufficient stowage room, even more ought to be taken. The necessity for carrying all this fuel is due to the fact that on a cruise of more than a few hours' duration round these coasts one is always liable to drop in for a strong head wind and its consequent sea, and as the fuel consumption per mile actually covered would thereby probably be doubled, such a contingency should always be reckoned with. Then again one has to consider the effect of adverse tides, which may greatly increase the mileage through the water if, owing say to a strong head wind, a tide is missed.

Stores and Spares for the Motor.

On no account should a cruise be undertaken without a good supply of engine stores, such as lubricants, waste material for making joints, asbestos, etc., also an assortment of spare parts, such as plugs, valves, valve springs, and perhaps some piston rings, although it would probably be an awkward job to replace a piston ring at sea in a small boat unless the weather were fine. A small box of odds and ends, including nuts, washers, and split pins, with some pieces of sheet copper and a few pipe connections, will often save a lot of trouble when small breakdowns occur. Tools should, of course, be provided, but it should not be forgotten to give them and all iron or steel articles among the spares and stores a coat of vaseline or tallow before they are stowed away. A thoroughly good and efficient anchor and a cable of ample length should be provided, while the addition of a light kedge and warp will frequently save a lot of trouble when it is desired to bring up in smooth water for a short time only. On any boat smaller than a motor yacht of considerable size, a good sweep should be carried, or in the case of boats under 30ft. a stout pair of oars and rowlocks. Most of the boats which make cruises round the coast are more or less auxiliaries, properly rigged and fitted with sufficient sail area to make them independent of the motor in the event of a breakdown, but when the boat depends solely upon motor power she should certainly be provided with a small mast and sail.

Lights and Signals.

A proper set of masthead, side, and anchor lights of fair size must be carried, otherwise trouble will very probably be experienced at night. If small or poor quality lamps are used they will not give enough light to be of any use, or most probably they will go out if there is the least bit of wind. In addition to a horn or an air whistle, a bell will always be useful, for one might have to anchor in a fog—a frying-pan beaten with a spanner does not make a bad substitute at a pinch. In emergencies a piece of waste, soaked in petrol and tied upon a piece of wire, makes a capital distress signal when lighted, but as there is always a grave danger of fire it should only be used in extreme cases. It must be remembered that the improper use of distress signals is visited with very heavy penalties.

Clothing.

In the matter of clothing, a blue serge suit and canvas shoes will fulfil all requirements in ordinary weather, but on cold, windy days there is nothing like a Danish kid suit such as is worn by motorists ashore. This substance not only keeps out the wind, but will stand a fair amount of rain and spray. Should, however, it pour with rain for some hours oilskins must be worn, for Danish kid will, in course of time, become sodden and let the wet through. A suit of dungaree overalls should be kept for use when "monkeying" with the engine or other dirty jobs, and a sweater will often be found a comfort. For head gear an ordinary yachting cap is de rigueur at such places as Cowes, but at sea the example of the hatless brigade is an excellent one to follow.

Don't forget that the nights are generally very cold at sea, even in the height of summer, so be sure to take plenty of warm clothes, a heavy overcoat for night watches, and a supply of thick blankets or rugs. Jaeger sleeping bags can be recommended in lieu of ordinary bedding.

Stowing Stores for a Cruise.

Before leaving port, see that all stores and gear are properly stowed, especially the fuel. If much long-distance cruising is anticipated when the boat is being built, it will be as well to fit extra large fuel tanks at once, but if the boat already has a fair-sized tank, it will not be worth while altering it just for one or two cruises. In this case, the spare petrol must be carried in its native tins, but they should always be carefully stowed out of the way and secure from damage.

The amount of gear carried should be reduced to a minimum—the novice always takes a lot of useless things with him—and only such articles carried as are absolutely necessary. A mattress and sleeping bag for each person, which must be stowed away in waterproof kit bags during the day; a few cooking utensils, two Primus stoves, plates, cups, knives and forks, teapot, a can of oil, a two-gallon jar of water, candles, a few tea cloths, and a supply of cotton waste, should meet the requirements of the culinary and domestic department.

The inventory should also include a good riding light and a spare anchor and warp. Should the owner contemplate being under way at night, he must also carry a masthead light and combination red and green light in order to comply with the regulations for the prevention of collisions at sea. No vessel, however small, should go to sea without a compass; and, for a little boat, a liquid one will be found the most serviceable. Other articles likely to be of use are a hand-lead and line and a few tools, whilst a light bamboo rod of eight or ten feet in length will prove invaluable for taking soundings in shoal water.

The Dinghy Problem.

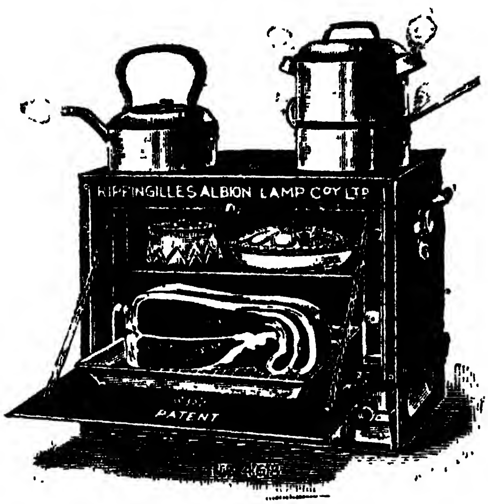
With a motor cruiser of five tons and upwards, a dinghy is almost a necessity, but its presence on a long sea passage is a terrible nuisance sometimes. If it is towed astern, the painter is always trying to get round the propeller every time the yacht slows down, and the dinghy runs up alongside. Going astern becomes worse, especially if it is towing with the long painter necessary for rough sea work. Whenever there is a dinghy towing astern, someone should make it a duty to see that the painter is shortened up and kept clear of the screw, as soon as the yacht is likely to have to slow up suddenly or go astern. Perhaps the best plan is to get it on board altogether if there is room (the cabin top is often a good place to stow it), but wooden dinghies are rather awkward to handle on a small yacht.

Stoves.

The marine motorist who has had no experience of cruising or camping will probably be at a loss as to what form of cooking-stove to buy, and we propose to point out the advantages and defects which, in our opinion, attach to the various stoves generally in use on small craft. But let us first consider the question of fuel, The yachtsman has not a large selection at his command, for the only forms of fuel at all practicable for the work are coal, coke, methylated spirit, and paraffin. Of these the first two can be dismissed in a few words, for a coal or coke stove intended for cooking purposes must be fitted with an oven. Such a stove is both large and heavy, and consequently only suitable for craft of considerable size. Coal is, moreover, a very bulky form of fuel, and would occupy much valuable space which can ill be spared on a small motor boat Methylated spirit is clean, stows in a small space, and gives great heat. On the other hand, it is rather costly, and not readily procurable at the small villages which the marine motorist is likely to visit in the course of his travels. Paraffin, on the whole, is the best form of fuel available for use on a small yacht, for it is cheap, and can be procured anywhere. Moreover, if the motor be driven by paraffin, as in a great many cabin craft, one tank will supply all requirements, as paraffin is undoubtedly the best and most convenient form of fuel for lights. Now let us turn our attention to the various types of stove on the market.

The coal stove is quite unsuitable for small craft; but on a fairly large yacht, with a roomy fo'castle, such a stove could be fitted forward, and would not interfere with the comfort of the owner and his friends. The men, however, would probably complain bitterly of the heat during the summer months. For camping in an open boat, when every inch of stowage space is of importance, the old Boddington stove is a type which takes a deal of beating. It is very compact, and fitted in a galvanised box to protect the flame from draught. A set of cooking utensils so made that they fit inside of one another completes the cooking outfit. When not in use the utensils pack inside the case with the stove, and the whole concern occupies but little space. Methylated stoves, however, have at times a nasty knack of exploding, and although such an explosion seldom does more than blow the wick out of the stove, it might be the cause of setting the boat on fire.

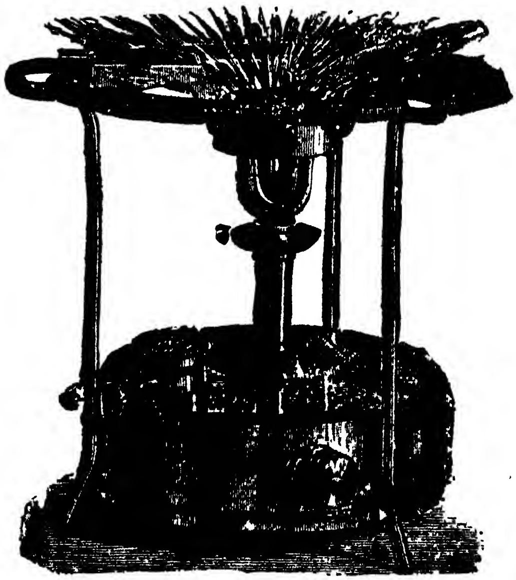
Paraffin stoves can be divided into two distinct classes—those with wicks and those of the atmospheric wickless type. Of the former variety the Rippingille is the pattern most generally used, though in our experience there are others equally good. A characteristic to be guarded against in many paraffin stoves is their tendency to smoke after burning for some time and getting thoroughly warm. The remedy is of course obvious; the flame must be watched and turned down after burning a few minutes.



Rippingille's Stove.

A preferable wick stove is the "Salamander," This is very similar in appearance to the Rippingille, but has a peculiar form of burner, which produces a flickering blue flame somewhat akin to a Bunsen. It gives more heat than the ordinary wick stove burner, consumes less oil, and is not so liable to smoke. The Salamander stove has a nice little oven, which will cook small joints or poultry admirably. Like all wick stoves, however, it requires cleaning and trimming, which is often an irksome task, particularly should it have to be done at the conclusion of a long passage.

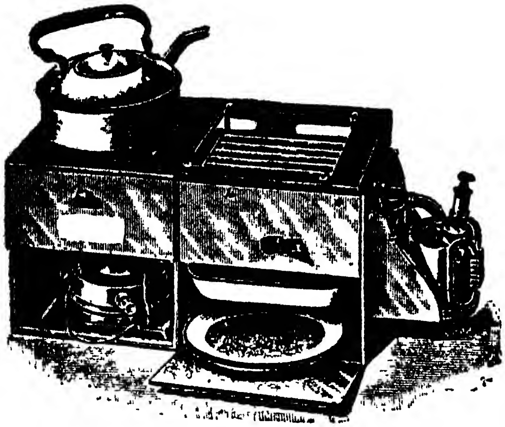
A type known as the Primus atmospheric oil stove is unequalled for small yacht work. It is very economical, compact, gives great heat, and, being wickless, requires no cleaning. The heat can be adjusted to a nicety, and if upset the oil does not come out. The Primus stove is nowadays pretty well known, but for the benefit of those unacquainted with it a brief description may be of interest. There is a round brass oil reservoir standing on three legs, which are carried above the stove to form a rest for the cooking utensil. From the centre of the reservoir rises a short tube, surmounted by the burner, and attached to the tube below the burner is a little metal cup. In the reservoir is a small pump fitted with a valve for releasing the air pressure when desired. There is also, of course, a hole for filling the reservoir, which is closed with a screw cup, fitted with an india-rubber washer to render it air-tight. So much for the stove itself; and now to describe the modus operandi. The first thing to do is to fill the reservoir with paraffin and screw the cap down tightly. Then the cup below the burner is filled with methylated spirit—it only requires about a dessertspoonful—which is ignited. When the spirit has nearly burned away the valve must be closed, and a few strokes on the pump will cause the burner to light. The principle is as follows:—The flame from the methylated spirit burning beneath the burner thoroughly heats the latter. When air is pumped into the reservoir it causes the paraffin to rise in the tube, and, passing through the hot burner, the oil becoming vaporised issues from the nozzle in the form of a gas, which burns with a blue flame. The heat is intense, and the more the stove is pumped the hotter becomes the flame. When well pumped up the Primus stove will boil a quart of water in four minutes, and the flame, being free from carbon, does not black the cooking utensils. By means of the valve the heat can be regulated to a nicety. To reduce the pressure the valve is opened until the flame is of the desired size, when the valve is closed again. To put the stove out the valve is left open. With a reasonable amount of care the Primus stove seldom gets out of order, but occasionally the tiny hole in the nozzle of the burner becomes clogged and requires cleaning out with a special pricker, a supply of which always accompanies the stove. The chief cause of the burner being thus clogged is the presence of grit in the oil, and if, when filling the reservoir, the paraffin is strained through a piece of rag the burner will seldom require pricking out. When lighting the stove one should be careful that no draught plays upon it, for if the flame from the burning methylated spirit be blown aside the burner will not be sufficiently heated to vaporise the oil. In such circumstances when the stove is pumped the oil emerges from the burner in its natural state, and a somewhat alarming flare up is the result. Should this happen the valve must be at once opened, when,



The Primus Stove.

the pressure being relieved, the flame will subside to such proportions as to allow of it being blown out.

It is, of course, necessary to point out that this stove should be placed as far as possible



An improved form of Primus Stove.

from the petrol tanks or from any part of the boat where petrol vapour is liable to accumulate.

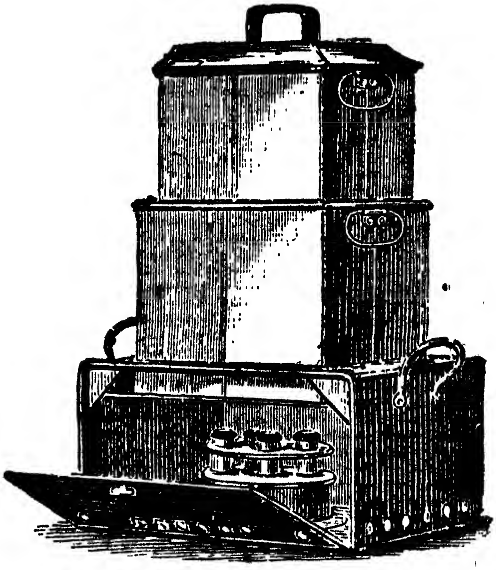
An improved form of this stove has recently been introduced which seems particularly suitable for small boat work in that it has two burners. As it is often necessary to use two cooking utensils at once this double stove will answer the purpose admirably, and will occupy less space than would two single ones. The majority of men who go down to the sea in three-tonners are content to confine their cooking operations to frying and boiling, consequently a large stock of utensils is not necessary. The chief articles wanted will be a good-sized frying pan, a kettle, and a double saucepan. The frying-pan should be of the good old-fashioned iron type, for the enamelled ones are little short of a nuisance. They invariably have a convex bottom, and all the gravy running to the sides, the succulent steak, or whatever it may be, is burnt. By the use of a double saucepan two vegetables may be cooked at once, or it can be used as two saucepans if so desired. The saucepan and kettle should be enamelled to prevent rusting. The marine motorist should on no account be led into buying aluminium cooking utensils, or, for that matter, anything fashioned of that metal, as it will not stand salt water. With the aid of a wire gauze toaster, such as can be procured at most gas-stove shops, excellent toast can be made over a Primus stove. As a motor boat is seldom heeled over like a sailing yacht, it will not be necessary to have the stoves slung in gimbals, yet it is advisable to have them securely fixed so that they will not capsize when under way or brought up in rough weather.

There is a very ingenious stand now supplied for the Primus stove. It consists of a wooden base, which is fastened down to the cabin floor with a couple of screws. The base has three curved bits of metal fixed to it, which firmly grip the legs of the stove. All one has to do is to stand the stove on the base and give it a half turn, which causes the legs to engage in the pieces of metal. A special top for the stove can also be had, which prevents the cooking utensil from slipping off. With the aid of these implements one should experience no difficulty in cooking under way, except perhaps in a very rough sea.

Provisioning.

Never start on a cruise without sufficient provisions to last all hands for several days, and water enough for a week, as one never knows what may happen. Boats may easily get blown out to sea and be unable to make a port for some days. In small boats the water is best kept in stone jars covered with wicker cases, but on yachts it is usual to keep it in a tank. This tank should always be cleaned out and refilled before starting. It is not advisable to attempt to keep enough fresh meat on board to last several days, as the accommodation for keeping it fresh on a boat is by no means good. With bread the same difficulty of storage is experienced, so the bulk of the breadstuffs should be biscuits. Good, lightly salted butter in a jar and some Dutch cheese will keep for a long time, and they are a great standby in bad weather when no one has time to get a proper meal.

The catering question is always a difficult one, but the great secret is to get fresh meat as often



A good type of stove for large boats.

as possible. Still, one must lay in a stock of canned goods for emergencies, and it makes all the difference whether a good brand be procured or otherwise. Amongst the best things put up in tins are steak and kidney pudding, tongues (both ox and sheep), various curries, also lobster, sardines, apricots, pineapples, and pears. A good stock of bacon (cut in rashers) and eggs should be carried for breakfast purposes, and as fresh milk is often not readily procurable a supply of condensed milk must be laid in. One or other of the unsweetened brands will be found excellent for those who do not care for sugar in their tea. As regards bread and butter, half a loaf per head of the former and 2oz. of the latter per diem should be a sufficient allowance. It is often difficult to make up one's mind on the question of lunch, but if one has a good dinner of fresh meat in the evening a light mid-day meal will suffice. For this purpose a stock of potted meats, biscuits, and cheese should be laid in, and of course one must not omit from the catering list such indispensable items as jam and marmalade. Thermos and Calorit bottles are also extremely handy for preserving or preparing hot soup, etc., at short notice or when no fire or stove is available.

Cabin Fittings.

As the marine motorist will spend a good deal of his time in the cabin he should take pains to make it as comfortable as possible, and with this end in view he will be well advised to devote some little attention to the question of cushions. There are two substances eminently suitable for stuffing purposes. The first of these is horsehair, which is expensive but eminently satisfactory; the other is Kapok, which is a species of Australian cotton. It is far cheaper than horsehair and possesses certain desirable features which are wanting in the latter. Kapok is wonderfully light and soft and does not mat with use. It has, moreover, extraordinary floating capacity, and has been adopted by the Board of Trade for life-saving appliances. Cushions stuffed with Kapok, therefore, also serve the purpose of lifebuoys and enable one to dispense with the usual cork buoys, which always seem to be in the way. The very worst material that one can use for stuffing cushions is flock; for, if they once get wet with salt water, they will ever after be damp. One can take flock cushions that have been wetted with salt water and dry them in front of the fire until they seem to be bone dry; but, on the first appearance of damp weather, they will be sopping wet again. For covering purposes one cannot do better than use an artificial leather, such as Pantasote or Pegamoid. Pantasote wears well, is impervious to damp, and is not easily scratched. The ordinary buttons used for upholstering purposes are made of iron covered with leather. These seem quite unsuitable for boat work, as the iron rusts and rots the thread with which they are secured. The consequence is that the cushions begin to shed their buttons after a few months' use, and then speedily get out of shape. Bone buttons would be far more serviceable, and if of the same colour as the cushion would not look unsightly. The bunk cushions, by the way, should be divided in such a manner that the lockers can be opened without moving the whole cushion.

For bed clothing the marine motorist cannot do better than use the Jaeger sleeping bags which have already been referred to, and if such a bag be not sufficient, a good travelling rug will be found a useful addition. To ensure a comfortable night's rest a soft pillow is indispensable. A small down pillow such as is used in a baby's perambulator answers admirably, for it is easily stowed within the cot when not in use. As, however, this will not of itself be sufficient, a Kapok lifebelt pillow should be used in conjunction with it.

Inventory.

The following is an inventory of such articles as are likely to be wanted in connection with the domestic economy of a small motor cruiser, compiled for a party of three :—

Blankets and pillows, three towels, three white table-cloths, half-dozen tea-cloths, half-dozen glass-cloths, two dusters, chamois leather, cotton waste for washing up, knife board, good pattern stove of suitable size, with holdfast stands, frying pan, double saucepan, bowl for washing up, saucepan brush, methylated spirit for stove, oil for ditto, clothes brush, three large plates, three small plates, three cups and saucers, three egg cups, two dishes, butter dish, one jug, one teapot, air-tight bottle for salt, pepper castor, tins for tea, coffee, and sugar, three tumblers, three large knives, three small knives, three forks, three dessert spoons, three tea spoons, corkscrew and can opener, bucket, bailer, mop, water breaker, egg box, clothes, and provisions.

SIMPLE NAVIGATION.

Navigation is the science of finding a vessel's position at sea and of conducting a voyage from one place to another by pre-determining the distance to be made and the course to be steered, having due regard to local influence.

There are two branches of this science, viz. :—

(1) Navigation by dead reckoning and cross bearings.

(2) Navigation by observation of the sun, stars, etc.

As it is more than likely that the ordinary motor-launch owner would not have a chance of navigating his craft by means of taking observations of the sun, stars, etc., for finding his position (this system being in vogue when a vessel is out of sight of land), we suggest that he should study navigation by dead reckoning and cross bearings, which is all that is necessary for coastal and channel cruising.

This method, which we intend to follow, consists in actually measuring the courses and distances made by the vessel, and from them computing the distance and direction between the port of your departure and the goal of your desire.

The principal instruments used in dead reckoning are the Compass, Log, and Lead line.

The compass shows the direction in which the vessel is travelling; the log measures the speed or distance. The lead is used when on soundings to measure the depth of the water and to ascertain the character of the bottom. These data, when referred to the chart, throw valuable light on the question of the vessel's position.

When approaching a coast in thick weather, or on a dark night, the prudent navigator will use his lead frequently.

In addition to these instruments the navigator requires for all his work accurate charts of the waters in which he may be cruising.

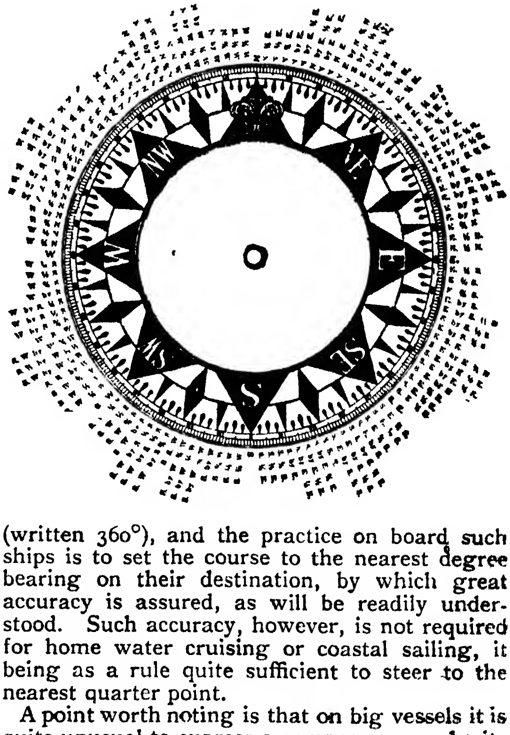
The Compass.

The Mariner's Compass is the first instrument with which the student must make himself thoroughly familiar. It is presumed that he has seen a compass, therefore its construction, etc., need not be described. The card is the part which is most important to the student.

A compass card is shown on this page which will give all the necessary information with regard to its details. The student should learn by heart all the points and quarter points, so as to be able to "box" the compass.

There are four principal quarters or divisions of the compass card—corresponding to the cardinal points, north, south, east, and west. Each is sub-divided into eight equal parts called "points"; the intervals between these points are further sub-divided into half and quarter points. In learning the compass it is well to remember that N. and S. are more important points than E. and W., hence the octants are N.E., N.W., S.E., and S.W. Again the intermediate points are N. by E., N.N.E., N.E. by N., N.E., N.E. by E., E.N.E., E. by N., E., and so for the other quadrants.

On ocean-going vessels the compass card is divided into 360 equal parts known as degrees



(written 360°), and the practice on board such ships is to set the course to the nearest degree bearing on their destination, by which great accuracy is assured, as will be readily understood. Such accuracy, however, is not required for home water cruising or coastal sailing, it being as a rule quite sufficient to steer to the nearest quarter point.

A point worth noting is that on big vessels it is quite unusual to express a compass course by its appropriate name, the rule being to express it as so many points and quarter points from north or south.

In this way N.W. by N. ¼ N. would be referred to as N. 2¾ W., or, E. ¼ S., would be expressed as S. 7¾ E., but, though E. might be called S.

Table for Converting Courses and Compass Bearings into Points East or West of North or South.

N.W. Quadrant.		N.E. Quadrant.	S.W. Quadrant.		S.E. Quadrant.
Name of Bearing or Course.	Number of Points from North.	Name of Bearing or Course.	Name of Bearing or Course.	Number of Points from South.	**Name of Bearing or Course.**
North	0	North	West	8	East
N. ¼ W.	¼	N. ¼ E.	W. ¼ S.	7¾	E. ¼ S.
N. ½ W.	½	N. ½ E.	W. ½ S.	7½	E. ½ S.
N. ¾ W.	¾	N. ¾ E.	W. ¾ S.	7¼	E. ¾ S.
N. by W.	1	N. by E.	W. by S.	7	E. by S.
N. by W. ¼ W.	1¼	N. by E. ¼ E.	W. by S. ¼ S.	6¾	E. by S. ¼ S.
N. by W. ½ W.	1½	N. by E. ½ E.	W. by S. ½ S.	6½	E. by S. ½ S.
N. by W. ¾ W.	1¾	N. by E. ¾ E.	W. by S. ¾ S.	6¼	E. by S. ¾ S.
N.N.W.	2	N.N.E.	W.S.W.	6	E.S.E.
N.W. by N. ¾ N.	2¼	N.E. by N. ¾ N.	S.W. by W. ¾ W.	5¾	S.E. by E. ¾ E.
N.W. by N. ½ N.	2½	N.E. by N. ½ N.	S.W. by W. ½ W.	5½	S.E. by E. ½ E.
N.W. by N. ¼ N.	2¾	N.E. by N. ¼ N.	S.W. by W. ¼ W.	5¼	S.E. by E. ¼ E.
N.W. by N.	3	N.E. by N.	S.W. by W.	5	S.E. by E.
N.W. ¾ N.	3¼	N. E. ¾ N.	S.W. ¾ W.	4¾	S.E. ¾ E.
N.W. ½ N.	3½	N. E. ½ N.	S.W. ½ W.	4½	S E. ½ E.
N.W. ¼ N.	3¾	N.E. ¼ N.	S.W. ¼ W.	4¼	S.E. ¼ E.
N.W.	4	N.E.	S.W.	4	S.E.
N.W. ¼ W.	4¼	N.E. ¼ E.	S.W. ¼ S.	3¾	S.E. ¼ S.
N.W. ½ W.	4½	N.E. ½ E.	S.W. ½ S.	3½	S.E. ½ S.
N.W ¾ W.	4¾	N.E. ¾ E.	S.W. ¾ S.	3¼	S.E. ¾ S.
N.W. by W.	5	N.E. by E.	S.W. by S.	3	S.E. by S.
N.W. by W. ¼ W.	5¼	N.E by E. ¼ E.	S.W. by S. ¼ S.	2¾	S.E. by S. ¼ S.
N.W. by W ½ W.	5½	N E. by E. ½ E.	S.W. by S. ½ S.	2½	S.E. by S. ½ S.
N.W. by W. ¾ W.	5¾	N E. by E. ¾ E.	S.W. by S. ¾ S.	2¼	S.E. by S. ¾ S.
W.N.W.	6	E.N.E.	S.S.W.	2	S.S.E.
W. by N. ¾ N.	6¼	E. by N. ¾ N.	S. by W. ¾ W.	1¾	S. by E. ¾ E.
W. by N. ½ N.	6½	E. by N. ½ N.	S. by W ½ W.	1½	S. by E. ½ E.
W. by N. ¼ N.	6¾	E. by N. ¼ N.	S. by W. ¼ W.	1¼	S. by E. ¼ E.
W. by N.	7	E. by N.	S. by W.	1	S. by E.
W. ¾ N.	7¼	E. ¾ N.	S. ¾ W.	¾	S. ¾ E.
W. ½ N.	7½	E. ½ N.	S. ½ W.	½	S. ½ E.
W. ¼ N.	7¾	E. ¼ N.	S. ¼ W.	¼	S. ¼ E.
West	8	East	South	0	South

8 E., or N. 8 E., it would of course be referred to as simply E. The accompanying table will be found valuable and facilitate changing compass courses and bearings into points.

Until he is master of all these points and their relation to one another he should go no further.

Variation.

The north point of the compass indicates true or geographical north at only a few places on the globe. At all other places it points a little to one side or to the other.

This error is called variation of the compass. In chart sailing it is not necessary to make allowance for this variation. The amount of allowance and its direction are indicated on the compass cards printed on the charts.

The north point will be found slewed a little to the eastward or westward of true north and near it will be seen an inscription such as variation 11 deg. W. in 1900. Variation may be explained as follows :—

"Let an outer circle represent the sea horizon, and an inner circle the compass card. The variation is one point westerly. Hence the north point of the compass points to north by west point of the horizon. In other words, standing in the centre of these circles and looking towards the circumference you find that every point of the compass is one point to the left of the proper place. If your compass says you are sailing north you are really sailing north by west."

Hence we get this rule :—

To Correct a Compass Course.—When the variation is *westerly*, the true course will be as many points to the left of the compass course as there are points of variation.

When the variation is *easterly* the true course will be as many points right of the compass course.

Deviation.

In addition to the magnetism of the earth, which affects all compasses alike, no matter how situated, we have to contend with deviation, which is a local error caused by the influence of neighbouring iron or steel, such as the motor itself or pipes, anchor and chain, shafting, etc. In vessels built of either of these materials the influence is great, and no compass on board such a vessel is ever quite correct, except possibly on one or two courses. As the compass card does not turn with the vessel when her course is altered, it follows that the mass of metal of which she is composed assumes new relations to the needle of the compass, and that,

as a result, the error caused by deviation must change whenever the course is changed.

This is what makes the problems arising from deviation very troublesome, and it makes it necessary to ascertain the amount of error on each course.

It is customary in merchant vessels to use compensated compasses. Before leaving port an expert called a compass adjuster ascertains the amount and direction of the deviation on the principal courses, and endeavours by introducing magnets in appropriate positions in the immediate vicinity of the compass to counteract it.

A certain amount of error always remains. This is noted by the adjuster, who furnishes the master of the ship with a table of residual errors, showing the amount and direction of the deviation remaining on each course after adjustment.

The corrections for deviation are applied in exactly the same way as those for variation. Use the same rules

Log.

There are two kinds of logs, the chip log and the patent or towing log. The latter is the most convenient for our purpose. The patent or towing log consists of a dial fixed on the taffrail, a line and a rotator of screw propeller form. The action of the water on the rotator, which is at the end of the line and thrown overboard, causes the line to make a certain number of twists a minute. These twists are proportional to the speed of the vessel, and they move the machinery of the dial, which records knots and fractions of knots. Directions for the use and care of patent logs are given by the dealers. All patent logs are liable to error, especially at low speeds. The rotator slips sometimes, and that underrates the distance. Usually, however, they overrate it.

When using the log you must allow for currents. If you are going against a current, the rate of which is known, you must deduct its rate from that recorded by the log. *If you are going with the current you must add its rate.*

Directions for making allowance for currents setting diagonally across the course will be given later on.

Lead Line.

The lead is used to ascertain the depth of the water, and, when necessary, the character of the bottom. The hand lead is all that is necessary for our purpose.

The lead weighs about 8lb., and has markings to 20 fathoms (120ft.).

The hand lead is marked thus :—

2	fathoms	2 strips of leather.
3	,,	3 ,, ,, ,,
5	,,	a white rag (bunting).
7	,,	a red rag ,,
10	,,	a piece of leather with a hole in it.
13	,,	same as No. 3.
15		,, ,, No. 5.
17		,, ,, No. 7.
20		with 2 knots.

The hand lead should be hollowed out on the lower end, so that an "arming" of tallow can be put in. This will bring up a specimen of the bottom, which should be compared with the description found on the chart.

Charts, etc.

It is hardly necessary here to give a complete description of a chart with all its meanings, etc. The following particulars should suffice :—

A chart is a map of an ocean, bay, sound, or other navigable water showing the formations of the coasts, heights of mountains, the depth of water at low tide, direction and velocity of currents and tides, location, character, height, and radius of visibility of all beacon lights, lightships, etc., location of rocks, shoals and buoys, and the nature of the bottom wherever soundings can be obtained. The top of the chart is generally north. If for any reason, otherwise, north will be indicated by the north point of the compass card printed somewhere on the chart.

The following particulars of charts can be learnt from a nautical almanac :—

Abbreviations on charts.
Lights and lightships.
Soundings.
Arrows indicating tidal currents and directions.

By means of the chart, the navigator may at times sail along a coast in clear weather without having recourse to any other instruments of navigation than the compass and lead line. The instruments used in consulting the chart are a parallel ruler and a pair of dividers. Parallel rulers are generally made of ebony. They are connected by cross pieces of brass or other non-corrodible metal, working on pivots in such a way that the rulers may be spread apart or pushed together, but will always remain parallel to each other. There are other forms of parallel rulers, such as a ruler of ebony with bevelled edges, made to run parallel with the edge of the ruler by means of two rollers that are let into the ruler so that the lower part of the rollers may roll on the chart.

The former kind are the best for the purpose, as they are not so liable to shift if they have to be moved over a crease in the chart.

They are used to determine the direction of courses. For instance, you wish to find the course, say, from Beachy Head to the Owers lightship. Lay the parallel rulers so that one edge cuts both places. Now slide first one rule and then the other, holding the unmoved one down firmly so as to retain the direction till the edge cuts the centre and circumference of the nearest compass printed on the chart. The edge, if the direction has been preserved, will indicate the course.

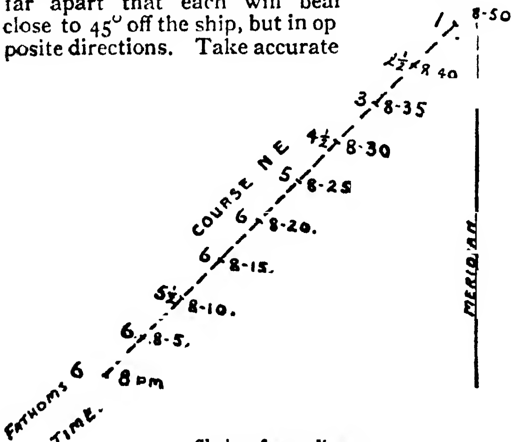
The student must remember that the variation is allowed for on the compasses printed on the chart, so that the above process is made more straightforward and simpler, except in the cases where the variation increases and decreases so

much a year after the chart has been published. This variation is generally to be found amongst the particulars of the chart near the title.

The dividers are used to measure distance. On small charts take your distance from the scale of nautical miles; on large ones from the latitude scale at the side of the chart. A minute of latitude is always a mile, because parallels of latitude are equidistant at all parts.

Chart Sailing.

To find the position of the vessel.—The best method is that by cross bearings. Select two clearly-defined objects marked on the chart. so far apart that each will bear close to 45° off the ship, but in op posite directions. Take accurate



Chain of soundings.

bearings of each. Correct the bearings for deviation. Then with the parallel rulers carry the bearings of the object from the compass card on the chart to the object itself, and rule a faint line with a pencil that can be rubbed out. Do the same with the other object. The intersection of the two lines will be the position of the ship at the time the sights were taken.

It would be as well to introduce another instrument at this point. The instrument we have in mind can be described thus:—It is an arm with an upright at each extremity. It is arranged so that these uprights are directly opposite one another, outside the circumference of the compass. Each upright is slit down the centre. In both is stretched a perpendicular hair, so by laying the instrument on the glass cover of the compass and aligning the two hairs on the object, one can get an accurate bearing by looking down through another slit in the arm fitted with a horizontal hair which is directly over the bearings indicated by the aligning of the two hairs.

The student will fully appreciate the use of this instrument in the method we have described in finding the position of a ship by taking bearings.

Having established the position of your vessel by cross bearings or by running close aboard of a lightship or buoy whose position is marked on the chart, you can give the helmsman the course, which has been ascertained by the parallel rulers according to the methods already described.

To find a vessel's position when sailing along the coast.—Take a compass-bearing of a light or other prominent object when it is 2, 3, or 4 points off the course. Take another bearing when it has doubled the first, and is 4, 6, or 8 points off the course. The distance run by the vessel between the two bearings will be her distance from the observed object at the second bearing. The distance run between these points must be observed by the taffrail log.

How to use compass, log, and lead in a fog.—Take a piece of tracing paper and rule a meridian on it. Take casts of the lead at regular intervals, noting the time at which each cast is taken and the distance logged between the two. A five minutes interval is sufficient between the casts. The compass shows the course. Now rule a line on the tracing paper in the direction of your course. Measure off on it by the scale of miles of your chart the distance run between the casts. Opposite each cast note the time and the depth obtained. It is a good thing also to add the character of the bottom. Now lay your tracing paper on the chart, which can be seen through it, in the neighbourhood of the position you believed yourself to be in when you made your first cast. If your chain of soundings agrees with those on the chart right under your course, all is well. If not, move the tracing paper about, keeping the meridian line due north and south, till you find the place on the chart that does agree with you. That is where you are. You will not find two places where you can get that chain of soundings on the same course and at the same distances.

It must be remembered that all soundings must be added to, or subtracted from, according to the height of the tide at the time the soundings were taken.

Here follows a diagram which can in nearly all cases be used to find the rise and fall of the tide:—

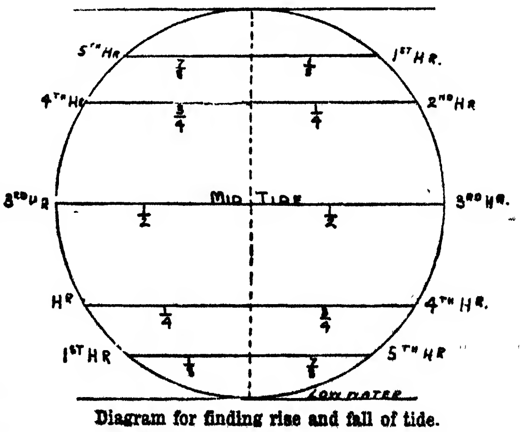


Diagram for finding rise and fall of tide.

Buoys.

The Uniformal System of Buoyage.—The principal arrangements of the system are as follow:—Channel buoys are understood to be marked from sea entering inwards or with the main stream or flood tide.

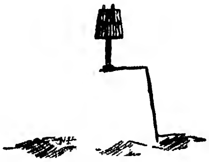
Conical Buoys, coloured red, are always to be left on the starboard hand.

Conical buoy.
(Starboard hand buoy.)

Beacon buoy.
Staff and globe (Starboard hand buoy).

Can Buoys are port hand buoys, and will be found painted with horizontal rings or vertical stripes, or sometimes chequered, the chart giving the nature of the painting in initials alongside the buoy, such as B.W. Ch., which indicates a black and white chequered buoy, whilst R.W. St. would mean a red and white striped

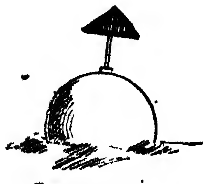
Can buoy.
(Port hand buoy.)



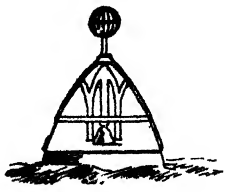
Beacon buoy.
Staff and cage (Port hand buoy).

buoy. Similar can buoys are also placed on spits of banks intervening between channels or middle grounds. The figures following the colour of the buoys on charts indicate the depth of water in fathoms in which they are at low water, spring tides.

Beacon Buoys.—Buoys surmounted by a staff and globe indicate starboard hand buoys, a staff and cage indicates port hand, whilst buoys with a staff and triangle are placed at the inner ends of middle grounds and at the outer ends a staff and diamond buoy.

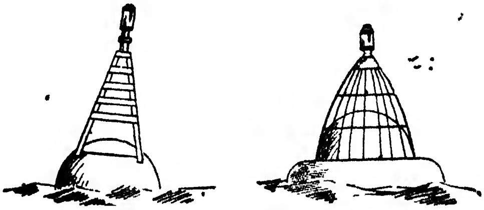


Beacon buoy.
Inner end of middle grounds.



Bell buoy.
Special or Fairway buoy.

Pillar or Bell Buoys (sounding by the action of the sea on the buoys) are used as special or fairway buoys. Gas buoys are used to indicate the channel at night, and may be either steady light or flashing, popularly known amongst seamen as "blinkers" These buoys are of various shapes and styles.



Two types of gas buoys.

Buoys marking submarine telegraph cables are coloured green. Wreck buoys (or ships marking wrecks) are also green.

Buoys at their best can only be looked upon as aids to navigation. Navigators should always verify their position by the bearing of lights or other objects on shore or by lead, as buoys, especially in exposed situations, are liable to shift their position

Navigation Tables and Formulæ.

DISTANCE BY VISION.

Altitude (feet).	Distance (miles).	Altitude (feet).	Distance (miles).
1	1.06	60	8.24
2	1.50	65	8.58
3	1.84	70	8.89
4	2.13	75	9.21
5	2.38	80	9.51
6	2.60	85	9.80
7	2.81	90	10.09
8	3.01	95	10.36
9	3.19	100	10.65
10	3.36	110	11.15
15	4.12	120	11.65
20	4.76	130	12.12
25	5.52	140	12.58
30	5.82	150	13.03
35	6.29	160	13.45
40	6.73	170	13.87
45	7.13	180	14.27
50	7.52	190	14.66
55	7.89	200	15.04

To ascertain the distance of a light from the observer, approximately:—Knowing the height of the light, add to this value the height of the observer above the sea level, and opposite the sum of these heights you will find the distance of the observer from the light. The altitude of any light should be corrected for the rise and fall of tide.

Here follows another simple method of finding the distance from an object, as recommended by W. B. Duncan, Nautical Teacher of South Shields.

Suppose you see a light unexpectedly. The sight makes you anxious; you want to know its distance from you. At once haul it abeam; you cannot approach it then. Go on that course un-

til it is one point abaft the beam. Then five times the distance you have gone since altering the course will be nearly the distance of the light from you.

Distance by Sound.

This table may be useful in determining distances by the time intervening between visible phenomena, such as the vapour from a whistle or the flash of a gun, etc., and the audible blast or report. The table may be further used in determining the distance of a storm.

This table gives distances in miles for intervals from one to ten seconds at an average summer temperature.

Interval (seconds).	Distance (miles).
1	.21
2	.42
3	.63
4	.85
5	1.06
6	1.27
7	1.48
8	1.70
9	1.91
10	2.12

To find the vessel's position by longitude.—This method entails the use of an accurate watch or chronometer, which must register Greenwich time. British navigators reckon their longitude east or west from the Greenwich meridian, and, as we shall see later, the computation of longitude consists in ascertaining the difference between the time at Greenwich and the time aboard the vessel.

Before proceeding any further the student should learn how to convert longitude into time, and vice versa. The conversion is based on the fact that the sun takes 24 hours to pass round the 360° of the earth's circumference. Divide 360 by 24 and you get the number of degrees he passes in one hour, viz., 15°. Therefore, 15° of longitude = 1 hour, and 1° = 1-15th of an hour, or four minutes.

To convert time into longitude, multiply the hours by 15 to get degrees. Divide the minutes by 4 and add the quotient to the number of degrees. If any minutes are left over, multiply them by 15. Divide the seconds by 4 and add the quotient to the minutes. Finally, multiply the remaining seconds by 15.

Example: Turn 5hr. 20min. 10sec. into longitude.

```
  5        4)20(5°        4)10(2'
 15          20             8
 --          --             --
 25          ...           2 × 15 = 30"
  5·         --             --
 --
 75
  5
 --
 80°
 --
```

Answer.—Longitude = 80° 2' 30".

To convert longitude into time: Multiply each member of the quantity by 4 and divide by 60, adding any figures left over to the result obtained from the next number to the right.

So now we have a method by which the student can in one way verify his position when he is sailing either due east or west. Say, for instance, we are proceeding down channel at night or in a thick haze, and we wish to know if we have gone past a certain landmark, all we need do is to make use of the above rule, in conjunction with the local time, e.g., the ship time. So now we can rule a faint line north and south on the chart at the point of longitude which we have worked out, and know that the vessel must be somewhere on that line. For any further exact knowledge of the vessel's position, we would have to go into the intricacies of latitude. As we wish to avoid this, the student must work out his position with what knowledge he has of the course he is on, and keep a bright lookout for any landmark or lightship which will show him where he is.

To find the Time of High Water.—To find the time of high water at full and change, as shown by the Roman numerals on the chart, add 49 minutes for every day that has elapsed since full or change, the sum being the p.m. tide for the day.

High Tide at any Port

In the Admiralty tide tables (of which we recommend every owner to obtain a copy), under the head of "Tidal Constants," a list of all the ports of any importance in home waters is given. In the column headed "Standard Port for Reference," opposite to your proposed port will be found the name of one of the "standard ports," as they are called, and in the column headed "Time" will be found also opposite to your port figures denoting hours and minutes, with the sign + (add) or — (subtract) affixed to them. These figures are known as tidal constants. Now turn to the pages giving the a.m. or p.m. tide for the day at the standard port, and when found (according to the + or — sign annexed to it) either add or subtract the tidal constant for your port; the result will give you the time of high water.

Care must be taken, however, to remember that when the tidal constant is +, and the result of adding it to the time of high water which is given at the standard port exceeds 12, then 12 must be deducted from that result for the purpose of getting correct time. On the other hand, if the constant given is —, and is larger than the number indicating the time of high water at the standard port, then 12 must be borrowed.

How to allow for the Set and Drift of a Current (diagram 1).—Let A represent the ship's place on the chart and D her destination, join A D, then the line A D is the course required to be made good. From A draw a line A B in the direction in which the current sets and equal to the distance it runs in one hour, then take with the dividers the distance the ship will log in one hour, and place one leg of the dividers at B, letting the other leg rest on the true course A D, at a point C; join B C. The

direction of the line B C taken to the nearest compass on the chart is the course to steer from A in order to counteract the current A B, and make good the true course A C.

Again, to determine the effect of the tide upon a ship's course, suppose the ship steers a N.E. by E. course, steaming at the rate of 10 knots, or from A to B (diagram 2), and suppose the tide to run north four miles an hour, or from B to C, by laying off these as two separate courses,

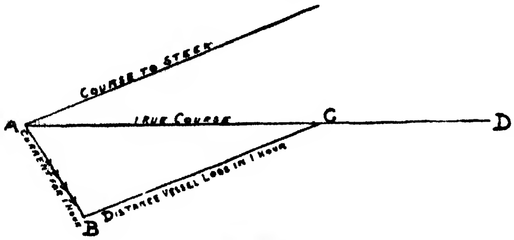


Diagram 1.

it will be seen that the course made good is from A to C, or N.E. ½ N. 12¾ miles.

Again, when shaping a course through a tide the operation is reversed; thus, in diagram 2, if the course to be sailed had been N.E. ½ N., the allowance of 1½ points to the right for the tide would make the course to be steered N.E. by E.

If the tide is marked 3 knots on the chart at springs, at the 1st hour, 2nd hour, 3rd hour, 4th hour, 5th hour, take 1 knot, 2 knots, 3 knots, 2 knots, 1 knot. If it be neap tides, take one-third from each of the quantities.

As a rough general rule, a vessel in the fairway of the channel will be carried at springs in one whole tide about 9 miles, and at neaps about 6 miles; but nearer the land on either side the rates may increase.

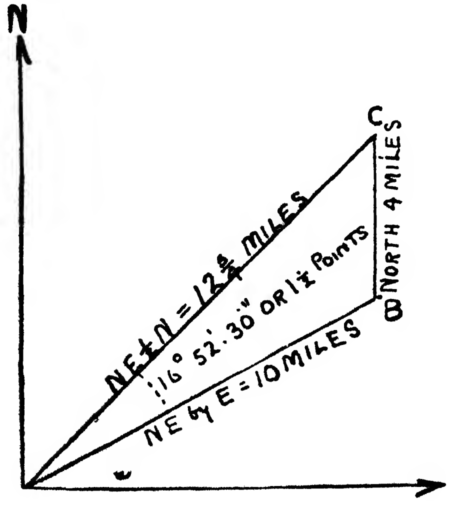


Diagram 2.

To Berth Your Vessel at an Anchorage.—Select the spot on the chart where you wish to let go your anchor. Note the depth of the water at mean low water (soundings are always marked for this state of tide), and have your anchor chain or cable overhauled for at least three times that depth. Draw a circle round the spot where you intend to anchor, with a radius of the same length as the chain or cable you have overhauled. See if you will have swinging room at all points of the circumference of the circle, and also plenty of room to get away, with the wind in any direction, for you may not be able to bring up just at the centre of your circle.

If possible, mark two cross bearings at right angles, in pencil, through the centre of your circle, so as to align with two separate double bearing marks such as houses on the shore (see sketch, p. 282). When you get these two bearings in line let go your anchor. After anchoring ascertain your exact position by new cross bearings and note the same in your log.

Signals.

A knowledge of the International Code of Signals is almost imperative, and we recommend that a copy of them should form part of the equipment of every boat destined for sea cruising. Full and clear instructions as to the use of the code is given in the handbook, and will well repay a careful study. The following, however, are a few of the more common signals, with which every navigator should be acquainted.

Fog Signals.—In haze, fog, or driving snow:—

(1) A steamship under way sounds one blast on her steam whistle at intervals not exceeding two minutes.

(2) A sailing vessel under way sounds at intervals not exceeding two minutes, one blast when on the starboard tack, two when on the port tack, and three when the wind is abaft the beam.

(3) Every ship when not under way rings a bell at like intervals.

Signals as to Steering.—A steamship warns that it is about to take a particular direction as follows:—

(1) One short blast on its whistle to indicate that she is directing her course to starboard.

(2) Two short blasts to indicate that she is directing her course to port.

(3) Three short blasts to indicate that she is going full speed astern.

It must be clearly understood that these signals are not compulsory, but if made the action must be carried out, and they should never be made unless the other vessel is in sight.

Signals of Distress.

I.—General.

(1) The letters N.C. (blue and white

chequered flag and white pennant) of the commercial code.
(2) The ensign upside down.
(3) A minute gun.
(4) Rockets (at night).
(5) Flames, from any combustible material (at night).

II.—Particular.
(1) Fire or leak, want immediate assistance; a ball over a square flag.
(2) Aground, want immediate assistance; a square flag over a ball.
(3) Want immediate assistance: the commercial code letters H.B. (red and white vertical and red swallow tail).

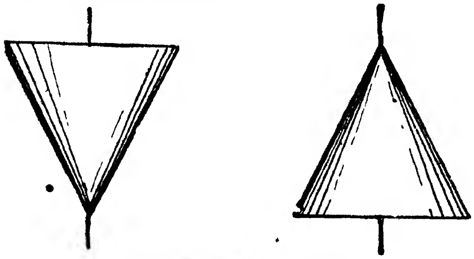
Warning Signals.
(1) Letters J.D. of commercial code (blue white, blue horizontal, and blue pennant with white ball) means you are standing into danger.
(2) A ball over a pennant indicates the same.
(3) Letters J.T. of commercial code (blue white, blue horizontal and red, white and blue vertical) indicates tack instantly.
(4) Letters K.F. of commercial code (yellow and blue vertical and red pennant) indicates bear up instantly.

As a rule, if a two flags signal is being made and the square flag is uppermost, it indicates something urgent; and if the letter J is uppermost it invariably conveys some warning.

Pilot Signals.—At any time during the day the signals for a pilot consist of the Union Jack with a white border, or the commercial code letters P.T. At night a bright flash light should be shown at intervals, or a blue light every 15 minutes.

Weather Signals.—A gale from the southward is indicated by a cone pointing downwards.

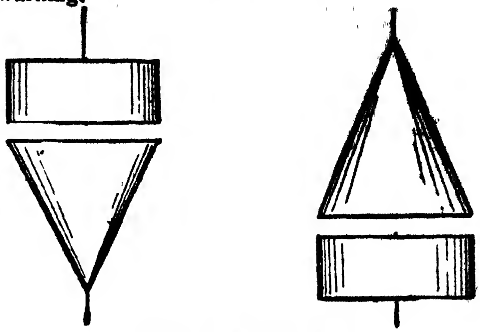
A gale from the northward is indicated by a cone pointing upwards.



Storm cones without drums.

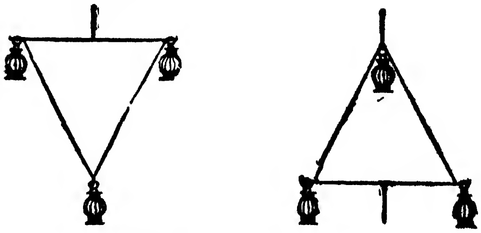
The cone is 3ft. high, and 3ft. wide at the base, and appears as a triangle when hoisted. On receipt at any signalling station round our coast of a notice from the Meteorological Office that an atmospherical disturbance is to be expected, a signal is hoisted, and remains during the day-time for 48 hours, counting from receipt of the message, unless the signal is countermanded in the interim.

Sometimes a drum is hung above or below the cone, which merely serves to emphasize the warning.



Storm cones with drums.

At night these cones are formed by three lanterns.



Storm warning, night signal.

The hoisting of any of these signals is intended as a sign that there is an atmospherical disturbance in existence which will probably cause a gale from the quarter indicated by the signal used in the neighbourhood (say within a distance of 50 miles) of the place where the signal is hoisted. Its meaning is simply, "Look out! It is probable that bad weather is approaching you."

Rule of the Road.

Having now described various methods of navigating a vessel by formulæ, charts and instruments, etc., it will be necessary for the student to learn how to navigate his vessel in conjunction with other vessels so as to avoid collision and probably loss of vessel and lives.

The student must learn the rules of the road at sea in such a way that he will know exactly what to do when such risks before mentioned arise.

The most convenient way to commit these rules to memory is as follows:—

(1) *Two Steamships Meeting.*
When both side lights you see ahead,
Port your helm and show your red.

(2) *Two Steamships Passing.*
Green to green, or red to red
Perfect safety—go ahead.

(3) *Two Steamships Crossing.*

Note.—This is the position of greatest danger. There is nothing for it but good look-out, caution, and judgment.

If to your starboard red appear,
It is your duty to keep clear;
To act as judgment says is proper—
To port or starboard—back or stop her!

But when upon your port is seen
A steamer's starboard light of green,
There's not so much for you to do,
For green to port keeps clear of you.

(4) *All Ships Must Keep a Good Look-out, and Steamships Must Stop and go Astern if Necessary.*

Both in safety and in doubt,
Always keep a good look-out;
In danger, with no room to turn,
Ease her! stop! or go astern!

N.B.—It is possible the student may not know which side of the vessel is port and which starboard. A vessel's starboard side and light (green) is to one's right, and the port side and light (red) is to one's left when standing on deck looking forward.

Naturally the term "steamships" in these rules refers to all vessels under power, such as motor craft.

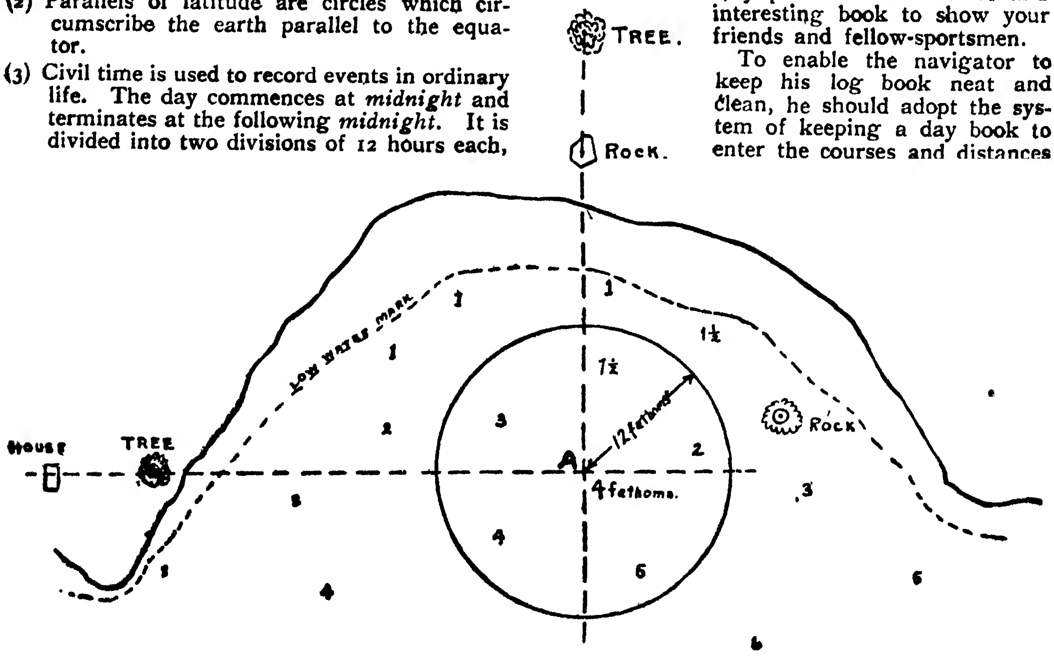
Definitions.

(1) Meridians are circles which cut the equator at right angles, and pass through both poles.
(2) Parallels of latitude are circles which circumscribe the earth parallel to the equator.
(3) Civil time is used to record events in ordinary life. The day commences at *midnight* and terminates at the following *midnight*. It is divided into two divisions of 12 hours each, the first being termed a.m. (ante meridiem), or before noon, the latter p.m. (post meridiem), or afternoon.
(4) Astronomical time is used in all astronomical calculations. The day commences at *noon* and terminates the following *noon*, without the distinction of a.m. or p.m.
(5) Variation of the compass is the angle the magnetic meridian makes with the true meridian.
(6) Deviation of the compass is the angle the compass needle (under the card) makes with the magnetic meridian.
(7) The error of the compass is the angle the compass makes with the true meridian.
(8) True course of a vessel is the compass course corrected for deviation and variation.
(9) Magnetic course is a compass course corrected for deviation.
(10) Compass course is the course steered by the vessel's compass.

Conclusion.

Before concluding these articles the navigator must understand the importance of keeping a log book in some form or other. It saves endless trouble should, for instance, the navigator wish to cruise over the same ground again; he has the courses and distances between the various ports, as well as a lot of local knowledge, so as to be able to anchor in a place where he can land easily and get supplies for man and motor. A log book, when neatly kept and perhaps illustrated with photographs and sketches, may prove to be a useful and interesting book to show your friends and fellow-sportsmen.

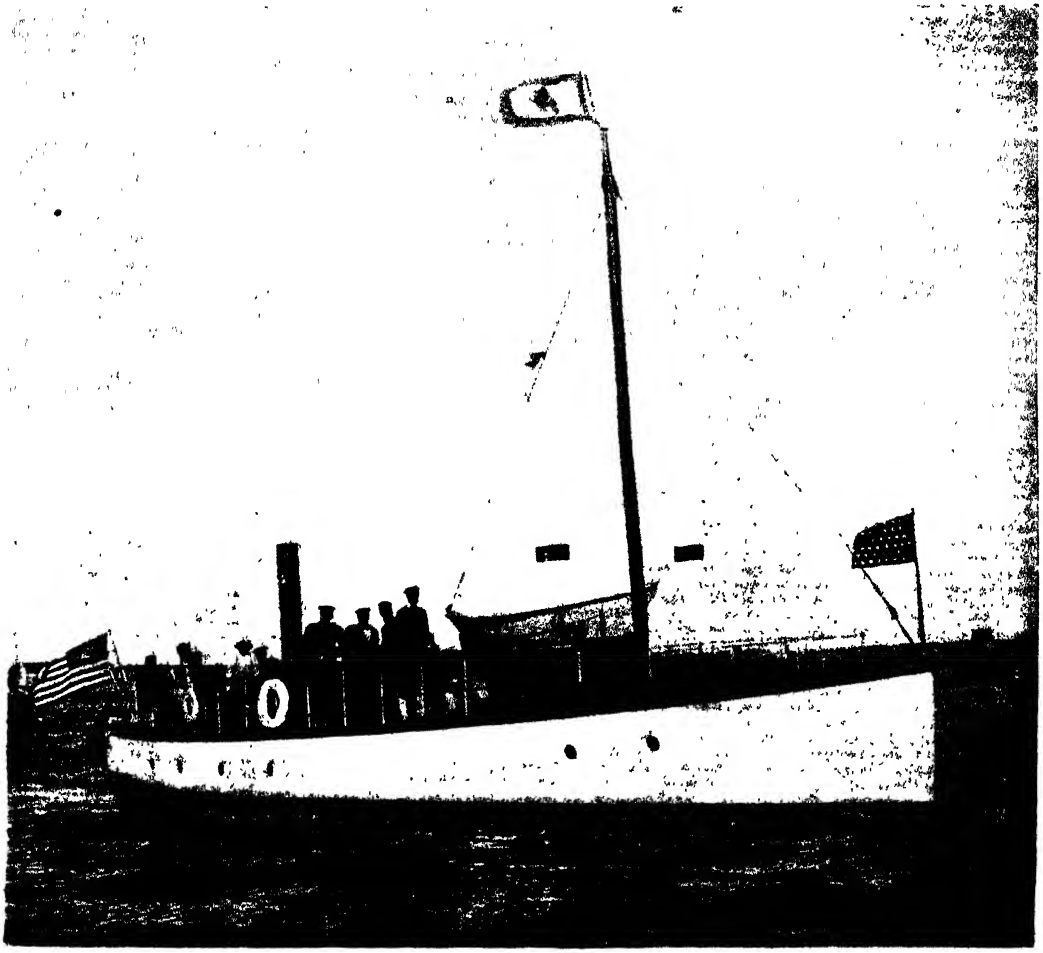
To enable the navigator to keep his log book neat and clean, he should adopt the system of keeping a day book to enter the courses and distances



A ship's proposed anchorage.

and times of passing the different objects, etc., and to enter them into the log book every evening after he has come to anchor.

Finally, remember you can never be too sure of your position. *Eternal vigilance*, especially at night and in a fog, is the price of safety at sea, and dangers increase when you approach the land. It takes time and practice to become an expert navigator, but any man with ordinary intelligence and careful application can be one if he perseveres, and every opportunity should be taken of acquiring information.



"Ailsa Craig," winner of the last New York-Bermuda Race.

SEAMANSHIP.

Some Notes on the Management of Craft under Various Circumstances, with Information on other matters which should be Comprised within the Knowledge of a Seaman.

Learning to Handle a Boat.

A motor boat in the hands of an expert appears to be one of the simplest things in the world to steer and bring alongside a landing stage with just enough way on to come up to her berth, and stop without any fuss or trouble exactly where she should do. But let a novice try to handle one for the first time, and he will soon come to the conclusion that seamanship, even in a river launch, is not quite so easily acquired as one might suppose.

Seamanship is the knowledge of what to do, and when and how to do it. No matter what the emergency may be, a good seaman should never be at a loss as to how to repair any damage that can possibly be repaired with the means at his command; he must also know what a boat will be likely to do under any conceivable conditions of tide, wind, or sea, and be able to have his boat under perfect control at all times when under way. He should also know what any other boat near him is likely to do if in competent hands, and, at the same time, he must so handle his own boat that others may know what he is going to do in plenty of time to avoid trouble.

A good seaman should be able to steer almost instinctively, and must know to a nicety the relative speeds of his boat, of the tide, and of any other boat near him.

Supposing the novice to have learnt enough about his motor, from the maker, to enable him to start it fairly easily and run it without serious mistakes, he must then proceed to learn the rule of the road at sea, which is the exact opposite of the rule of the road ashore. The principal rules are as follow:—

(1) *Meeting*: Two boats meeting must pass port to port, or in other words, keep to the *right*.

(2) *Overtaking*: When one boat is overtaking another, the *overtaking* boat must keep clear of the boat she is overtaking.

(3) *Crossing*: When two boats are approaching more or less at right-angles, the boat which has her right-hand or starboard side next to the other's left-hand or port side must keep clear.

(4) *Towing, etc.*: A launch or tug towing another vessel must not be expected to alter her course. A vessel in the act of turning, or going alongside a wharf or stage, should be given plenty of room by other vessels.

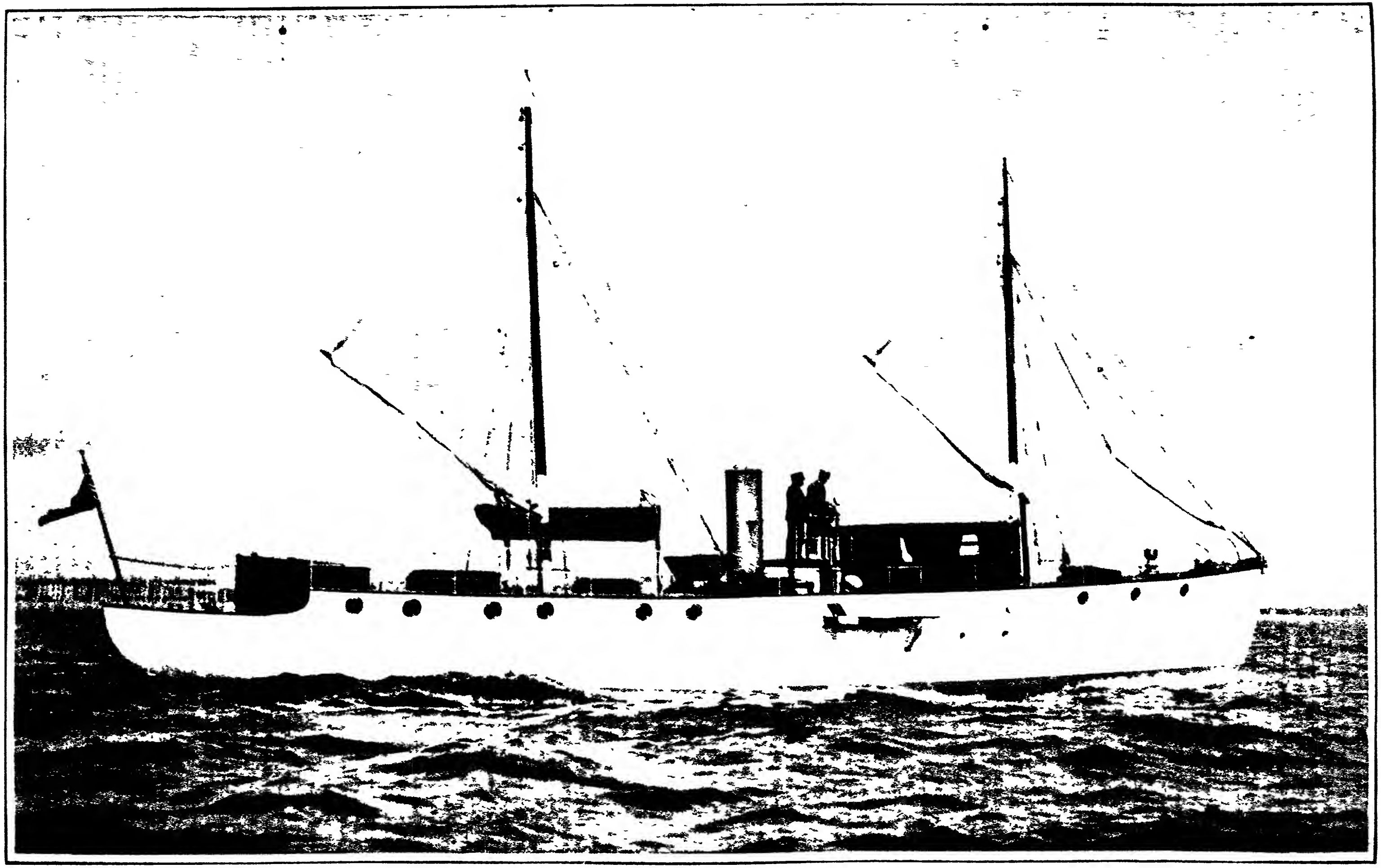
(5) *Power v. Sails*: All power vessels must get out of the way of sailing vessels of any description, no matter how they may be approaching one another. They should also keep clear of rowing boats, although it is allowable to blow a whistle, etc., to tell them to get out of the way in a crowded place.

(6) *Lights*: All power vessels must carry the regulation side lights and masthead light when under way between sunset and sunrise.

As soon as these regulations are learnt by heart, the next thing is to learn to steer. This is an instinct with all good helmsmen, like a horseman having "hands," but anyone can learn to steer a motor fairly well if he takes pains, and can concentrate his attention on his steering until it becomes second nature. Many a man who can really steer well, if he gives his mind to it, comes to grief simply through looking at other boats, or talking, and so taking his thoughts off the business in hand. One moment's absence of mind may cause an accident.

When steering, try to keep the stem of the boat in line with some fixed object ahead, and keep her on this course with as little alteration of the wheel as possible. Don't expect the boat to turn like a bicycle at a touch of the helm. She will take an appreciable time to feel it, unless the rudder has been jammed hard over; this should never be done except when absolutely necessary, as it may stop the motor, and is a sign of a bad helmsman. A good helmsman always coaxes his boat round, and never forces her if he can help it.

When going astern, it must be remembered that the helm will be reversed; but if the boat is steered with a horizontal wheel of the motor-car type, if the helmsman turns round and faces the stern, the steering will appear the same as when the boat is going ahead and he is facing forward. It is always well to remember, when steering a strange boat, that many boats steer very badly when going astern, especially when the propeller has just been reversed, whilst, in the case of a reversible-bladed propeller, when it



"Trident," a 77ft. motor yacht; her machinery installation consists of three 40h.p. Maudslay engines.

is in the neutral position, even if the boat is still going ahead, she may possibly take no notice whatever of the rudder.

Having learnt to steer, the novice should try to estimate the speed of his own and other boats. To do this, he should note at what rate his boat seems to be moving past the land as compared to another boat. If the other boat is between him and the land, he can see at once if he can cross ahead of her by noting whether the other boat is closing up any particular mark on shore, or opening it out; if she is closing up the marks, or the land appears to be slipping astern of her, then she will either cross ahead, or hit the observer's boat, if both boats kept their courses at the same speed. If, however, the land is opening out, and she appears to be going backwards past it, she will pass astern. The above rules also apply to a boat trying to clear a vessel at anchor or a buoy in a strong tideway.

When a man can steer and judge the speed of his own and other boats fairly well, he ought to be able to bring his boat alongside without much trouble, but it is not seamanlike to dash up to a landing-stage at full speed, and then go full speed astern just as the stage is reached. Another point of considerable importance is to be able to accurately judge the duration of time necessary for the boat to gather way astern from full speed ahead, and also the distance the boat will travel in that time. It is far better both for smartness and safety, to slow down in plenty of time, and come alongside quietly. In coming alongside, or picking up a mooring in a tideway, always come up head to tide if possible, and keep well clear of vessels at anchor or warps and buoys, when crossing a strong stream, as a nasty accident may occur should the motor fail or the propeller get foul of a warp.

When getting under way from moorings, attention should be paid so that the boat and propeller may keep clear of the buoy and buoy-rope etc. It is safest to drop astern to the end of the buoy-rope, and then give a sharp turn or sheer to one side so as to pass well clear of it.

With a little care and forethought, and the exercise of restraint in the early days of his novitiate, the novice will soon gain confidence in himself and the craft he is handling, and thenceforward it is generally all "plain-sailing."

Anchoring and Mooring.

Every owner of a motor boat should make himself acquainted with the proper methods of securing his boat when not in use. On a river this is a very simple matter on the non-tidal waters above lock, but, even so, very few owners appear to know how to make their own boats fast alongside a stage or bank.

Tying up to a Stage.

A stout rope of fair length must be provided at each end of the boat; these are known as the head-fast and the stern-fast. The inner end of each has a long eye splice, which is passed either through the mooring bollard or through a ring on each end of the boat, the rope then passing through its own eye to secure it to the boat, the other end being taken ashore to a fixed ring or post on the stage or bank. There it is either made fast with a bowline (see article on "Knots") or the end is brought back and made fast on the boat after being passed through the ring or round the post. Should the post be so short that the line is liable to slip off if merely passed round, it must be fastened to the post by a clove hitch, which will not slip.

Open Moorings.

Moorings are of many varieties, dependent on the locality and the size or type of vessel for which they are intended. It may be merely a chain attached to a heavy stone, buried in the sand or mud at low water; this is used if the boat be small and of a type suitable for lying ashore when the tide is out. Should, however, the boat have to lie afloat at all times of the tide, it is obviously an impractical plan, unless the bottom be so soft that the stone will sink into the mud and bury itself if left alone for a few days. Where this type of mooring can be used it is the best and simplest form obtainable and the least costly. The weight to be buried may be a flat paving stone, a lump of scrap iron, or, if it is to be buried by hand, a tree trunk will do, but the latter must be buried deep so that it will not pull out if a large vessel should get foul of the moorings. Whatever the form of the weight to be buried, it is essential that a short length of fairly heavy chain should be attached to it with a good free-working swivel, and from this the regular mooring chain should run to the boat.

For boats of anything over 25ft. in length the buried weight is unsuitable, unless it be of large size. It is therefore usual to lay down regular moorings for all but the smallest boats. Such moorings generally consist of a pair of anchors, each of which has one fluke cut off or knocked down on to the shank to avoid fouling the cable. The two anchors are connected by a piece of heavy chain at least three times as long as the depth of water in which the moorings are to be laid. In the centre of the chain—which is called the bridle chain—is a large shackle and swivel, to which the real cable, or riding chain, is attached. The size of the latter will be considerably less than that of the bridle, but its length should be about the same—three times the greatest depth at high water. On the upper end of the riding chain of all moorings a large ring or link should be fitted, and to

this the vessel is shackled when on the moorings; it also serves as attachment for the buoy-rope of coir, which must be long enough to allow the chain to rest on the bottom at high water and strong enough to hold the boat for a few minutes in bad weather until the riding chain can be got aboard.

Laying out Moorings.

To lay down a set of moorings such as those just described is by no means an easy job for an amateur. The following method will give an idea of the *modus operandi.* A quiet spot should be chosen in a part of the harbour where there is little or no traffic, but sufficient water to enable the boat to lie afloat in three or four feet at the lowest spring tides. A couple of old smacks' anchors, weighing some 30lb. or 40lb. apiece, and about 60ft. of old chain should be procured locally. The purchase should then be taken to a blacksmith for the purpose of having one fluke knocked down on the shank of each anchor and fastening the ends of the chain to each anchor with a large new link, at the same time cutting the chain in the centre and welding the cut ends into a ring, to which is attached a large swivel. The load of old iron should then be taken down to the quay, and, procuring the loan of a smack's boat, together with a couple of oarsmen, proceed to the spot selected, having first obtained permission from the harbour master to put down the moorings. Whilst rowing down the harbour the new quarter-inch galvanised riding chain should be shackled to the swivel, and some 25ft. of 3in. grass or coir rope and a small gallon keg attached to the other end, thus obtaining the buoy and buoy-rope. Starting above the spot selected, one anchor should be carefully lowered to the bottom by means of a line passed through the space between the shank and the fluke which has been knocked down; the weight of the other fluke keeping the anchor from turning over as it is lowered. The first anchor being safely in its place, at once row as hard as possible with the tide to pull it home into the ground and stretch the ground chain or bridle as it is paid out over the stern. When half the ground chain is paid out in this manner we come to the swivel to which the lower end of the riding chain is attached, and for the rest of the distance pay out both chains at once, taking care to keep them separate and clear of each other. As soon as all the ground chain is out, and the second anchor, the buoy-rope, and surplus length of riding chain alone remain in the boat, lower the anchor carefully to the bottom, right side up as before. Then, with the two parts of the rope by which it has been lowered made fast to the stern, row as hard as possible to thoroughly stretch the ground chain before letting go. The moorings are then ready for use, with nothing to catch or foul the cable.

Coming up to Moorings.

Although picking up moorings would seem a very simple matter to the uninitiated, it is nevertheless an evolution requiring some considerable knowledge and judgment, especially in a crowded anchorage or in a strong tideway. Even on a quiet river a lot of trouble may be saved by the exercise of a little care and skill when coming alongside a berth, but on salt water an apparently trivial mistake may have disastrous results either to one's own boat or to other craft moored near by. It should always be borne in mind that any damage done in this way must be paid for by the man who makes the mistake.

The golden rule when picking up a mooring or anchoring is to come up head to the tide, and so regulate the speed of the boat that she comes quietly to a stop with her bow just touching the buoy of her moorings; this is the great test of smartness, and is carefully observed by sailors. If she is about to anchor, she should stop exactly where it has been decided to drop the anchor. In this connection it must not be forgotten that, when anchoring, cable to at least four times the depth at high water must be paid out, and also that when the tide turns your boat will swing round her anchor, making a circle equal to the range allowed by the cable. It is therefore necessary to choose a berth where she will have plenty of room to swing clear of other vessels and obstructions. If the space available is limited, drop the anchor nearer the vessels up-stream of your boat, rather than to those astern, as they will all swing the other way when the tide turns and your boat will then remain clear. There is one exception to the foregoing rule of bringing a boat up head to tide—that is when the wind is much stronger than the tide and against it—in this case come up head to wind.

Mooring Gear in Whale-decked Boats.

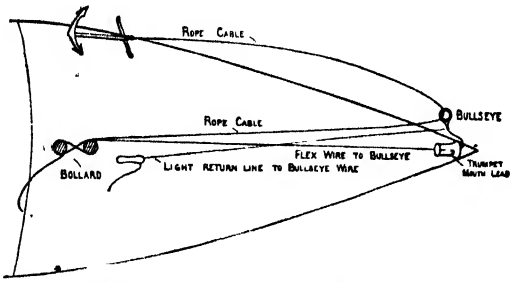
The operation of anchoring or picking up moorings on a racing or other boat is usually one of considerable difficulty if the boat is fitted with a round whale back extending over a considerable portion of her length.

The danger of going forward on a deck of this description, even when the boat is at rest, is often considerable if there is a little sea on, and this risk is greatly increased when the boat is travelling, and perhaps pitching or rolling at the same time. It is therefore very desirable to fit some arrangement by means of which the anchor can be let go or got aboard, and moorings slipped or picked up, without the necessity of a man going forward at all, whilst at the same time the cable, mooring, or tow-line is properly led from the stem head.

Such an arrangement has been in use for many years among canoeists, who often cannot leave the cockpit or get forward of the mast without capsizing their tiny craft.

This gear, in a form suitable for use on, say,

a 40ft. racing launch, consists, in the first place (see diagram), of a good trumpet-shaped fairlead. Through this lead is rove a piece of flexible wire rope (Tobin bronze for choice) of sufficient length to reach from the stem to the large mooring



Mooring gear for whale-deck boats.

bollards or cleats, which should be easily accessible from the cockpit. The outer end of the wire is spliced round a lignum vitæ bull's-eye having about an inch hole in it, while the inner end has a large eye splice which just fits over a stout eye-bolt in the deck alongside the bollard, and is secured by means of a toggle-pin through the eye-bolt over the wire. A piece of light line is spliced into the inner eye and, passing round the mooring cleat or bollard, is then carried forward and spliced round the wire just behind the bull's-eye, but outside the fairlead on the stem.

The cable is now rove through the bull's-eye and the end brought aft to the mooring bollard, where it is made fast while under way. To anchor, all that is necessary is to make the outer end of the cable fast to the anchor and drop it over the side, when the cable will at once run out through the bull's-eye in the end of the wire, which is now close up to the fairlead on the stem head. When sufficient cable has been paid out it can be made fast round the bollard, from which the boat will ride.

To get the anchor up again, the cable is hauled in from the cockpit until the anchor is chock up to the bull's-eye at the stem head. If the toggle-pin is now pulled out of the eye-bolt on deck and the inner end of the wire rope released, the anchor can then be hauled aft to the cockpit along the boat's side as the wire pays out through the fairlead on the stem. As soon as the anchor can be reached it is lifted into the cockpit after washing off any mud, etc., and, by hauling in on the small line, the inner end of the wire can be brought back, the bull's-eye and the bight of the cable being hauled out to the fairlead again. When the inner eye on the wire is again slipped over the eye-bolt and the toggle-pin replaced, the cable is again ready for anchoring or mooring.

Mooring in Whale-deck Boats.

The only difference between mooring and anchoring is that, when mooring, the boat must be carefully brought alongside the mooring buoy, head to stream or wind, and the buoy taken into the cockpit while the buoy rope is overhauled until the mooring chain is reached, to which the outer end of the cable must be made fast. The buoy is kept in the cockpit and the end of the mooring chain is hauled close up to the bull's-eye at the stem head, the cable being then made fast, together with the slack of the buoy-rope on the mooring bollard.

Slipping Moorings.

To get away from the moorings, first throw the buoy overboard, then let go enough cable to enable you to haul the end of the mooring chain into the cockpit by the buoy-rope and unbend the cable from it. The mooring and buoy-ropes may now be let go over the side, taking care they do not foul the propeller or rudder.

A large spring hook, strong enough to ride to, may be spliced into the outer end of the cable, and will be found to greatly facilitate matters both in anchoring and in mooring—the latter more especially—but great care must be taken to get such a hook of ample strength, or the boat may go adrift.

A variation of the foregoing arrangement is to have a spring hook in the end of the wire instead of the bull's eye; the mooring chain is then hooked direct to the wire, which is, of course, first hauled aft by a small line, and then the wire is hauled back through the fairlead and made fast, as before, with the mooring close up to the stem head.

Towing.

Towing or being towed in a motor boat sounds a very simple matter, and it is not until one has had experience of it in a little bit of sea that its true inwardness is appreciated.

Next to a good lead for the tow-rope at the stem head, the most important point in towing is good steering and unceasing vigilance on the part of the helmsmen of both vessels. Not only must the vessel which is being towed be kept from yawing about, as she is always liable to do, but she must also carefully follow every turn made by the tug, not at the same moment, but at the same spot. Thus if the tug at a given spot turns off to starboard, then the tow must make a similar turn at exactly the same place. If she were to turn to starboard at the same moment as the tug, the result would be that the two boats and the tow-rope would be somewhat in the form of the letter Z, and the tow would, if of sufficient size, pull the tug round alongside her, besides risking breaking the tow rope. This frequently occurs when a sailing yacht is being towed by her own dinghy: a puff of wind catching her sails sends her along faster than the dinghy and to one side of it; thus bringing it up alongside stern first.

How to Tow.

When towing a boat which is liable to steer badly, such as a racing motor boat, the greatest care must be exercised on the part of the tug, not only to go at a suitable speed, but also to see that the tow-line is properly made fast both on the tug and on the tow.

If the tug is the larger vessel, she may tow from the stern bollards or any convenient point right aft, but if she is the smaller, as in the case of an ordinary tug and a large ship, then she should tow from some point just abaft amidships, otherwise she will be unable to manœuvre with any freedom, as the greater weight of the tow will prevent her answering her helm and turning as she wishes.

Another point to be borne in mind is, that the line must be so made fast that it can be let go instantly in the event of any trouble occurring on either vessel; consequently it should never be hitched round a bollard, but merely made fast by means of several crossed turns which can easily be cast off. Do not forget, however, when casting off these turns with a heavy strain on the rope, that the latter may take charge as the last turns are cast off, and pull you overboard before you can let go, or else jam your hands on the bollard. If you have to cut the line to save the tow from a capsize, stand clear of the end or you may easily get a broken limb from the back lash of the cut end.

When first taking the strain on the tow-line, someone on either the tug or the tow must stand by to ease up a fathom or so of the line round a bollard, to avoid the heavy jerk which would otherwise come when the line got taut between the two vessels, and which might easily break the rope, but here again care must be exercised to avoid damage to the hands as the rope renders round the bollard.

Length of the Tow Rope.

This is a question which can only be settled according to the special circumstances of each individual case, but as a rule the heavier the sea, the longer the tow-line. In some cases where large vessels are being towed in a heavy sea enormous lengths of tow-line are used, and to ease the pluck on the line when they pitch opposite ways, a piece of chain is placed in the middle of the line to act as a spring by its weight. In smooth water, if the towed boat steers badly, the line may be shortened up until the two boats are nearly touching, but in this case a large fender should be hung over the stern of the tug to prevent damage when the tow runs ahead suddenly.

Towing Alongside.

This is a favourite method of towing in smooth and narrow waters. but it is very likely to cause considerable damage if there is any sea, owing to the great strains set up when the vessels grind together. In the case of a sinking boat, this is the only way to save her, provided the tug is large enough to support her weight alongside when full of water, but it is always likely to cause damage of some sort to the weaker boat of the two, unless the water is quite smooth. One of the greatest advantages of this method is that one man can steer both vessels and need take no notice of the tow when towing, so long as he remembers the extra width required for the two boats. Great care must be taken when lashing the two vessels together for this sort of towing to see that their keels are exactly parallel, otherwise there will be very heavy strains on the warps, and the tug will have a lot more work to do, owing to the increased resistance caused by towing a vessel out of the line of her keel.

Lying-to in a Heavy Blow.

Any sort of craft is liable to get caught in a hard blow when making a coasting passage, but, whereas a motor boat of considerable power is usually able to run in somewhere for shelter at the first sign of bad weather and before the sea gets too heavy for her, in the case of a low-powered boat, built only for comfortable sea cruising, with a maximum speed of, say, five knots in smooth water, it is quite possible to get caught in a nasty sea, against which the motor is quite powerless to drive her, even if it were safe.

A sea anchor is a thing about a boat you hope you will never require, because you seldom need it, but when you do want it you want it mighty badly, and in a hurry.

Probably the best and simplest method of making one with the materials at hand is as follows :

Close-reef the sail, and, having unshipped the mast, lash the heel of the yard to the fore-end of the boom; then lash the mast across the outer ends of the two, thus forming a rough triangular frame of three spars, with the sail fast to the sides of it. Attach a fairly heavy weight to the apex of the triangle where the yard and boom meet. By using the sheet and halyard doubled make a three-part bridle from each end of the spars, and to this bridle bend the end of a 30-fathom manilla cable. We are then ready to get the whole contraption overboard.

Before doing so, should there be a spare tin of lubricating oil on board, attach it to the junction of the bridle and the cable, first having pricked a small hole through the tin to allow a little of the oil to leak.

The oil leaking out of the tin will be found to very noticeably smooth the sea around the boat.

It should be here explained that the object of attaching the weight to the sea anchor is for the purpose of causing it to float vertically with the apex of the triangle downwards, thus affording the greatest possible amount of resistance. If

no canvas should be available, the sweep and floorboards can be utilised after the same manner to make a rough drag of some sort, and to break the seas.

It does not really matter much what sort of a sea anchor is used so long as some resistance is formed to prevent the boat blowing away before the wind.

Emergency Repairs to the Boat.

Stove In.

It occasionally happens that the most careful sailor, in spite of all due precautions and seamanship in handling his vessel, runs her ashore on rocks, or it may be on the stump of an old pile, and so gets a hole stove in her bottom. The fluke of an anchor is another frequent source of accidents of this description, and, although a good seaman should be able to tell within a little where all the neighbouring vessels' anchors lie, yet, in spite of all due precaution, it is very easy to leave a boat, as one thinks, in perfect safety, only to find on return that she has grounded on an anchor or a boulder and stove a few planks in. No matter how such an accident may have occurred, a temporary patch up must be made if the boat is to be got away and taken to the builder's yard to be repaired. The nature of such a make-shift repair must depend principally on the means at hand, on the extent of the injury, and, to some degree, on the character of the locality in which the trouble occurs.

Repairs of Small Leaks.

If a hole is fairly clean and small, a plug of waste and tallow or other grease may be rammed into it, and all leakage stopped at once. A simple crack in a plank can, however, easily be made good for the time being with a thread or two of cotton and some paint or grease forced into the crack with the point of a knife. On the other hand, the rent may be as large as one's hand, in which case prompt measures must be taken to prevent the boat sinking then and there.

Stopping Large Holes.

If the hole is fairly easy to get at, one should tear up the floor-boards or other obstructions and stuff a coat or mat into the hole, at the same time trying to bring that part of the boat out of water as much as possible by trimming the weights over to the opposite side or end of the boat. The coat may then be replaced by a piece of floor-board, covered with a plaster of grease and cotton waste (or handkerchiefs), and this should be firmly forced down over the hole by means of shores from the thwarts or other convenient portions of the boat. Such a makeshift should enable one to keep the boat afloat for some considerable time by dint of energetic bailing, and so get her into a place of safety, where she may be repaired. When the damage is underneath the engine or in some out-of-the-way corner of a locker, where it is impossible to get at it from the inside of the boat, the only thing to do, if the hole cannot be brought out of water by heeling the boat to the opposite side, is to pass a greased mat, or a piece of canvas, or cloth, over the hole from the outside and hold it in place with lashing right round the boat. Where some of the timbers of the boat are broken in addition to the damage to the planking, fresh timbers must be put in alongside the broken ones, but this is rather too big a job for the average amateur, and the same thing applies still more forcibly when the keel or garboards are strained. All these matters are for the boat builder to attend to, unless the owner has exceptional skill in that line.

A Foddered Sail.

When a ship gets a bad leak or a hole in her at sea, she is often saved by the use of what is known as a foddered sail hauled under her bottom by lines passed round her. This consists of a sail, awning, or other piece of canvas covered with tar, grease, and all manner of stuff like the wool from mattresses, oakum, etc. When it is hauled under the ship's bottom over the leak, the pressure of the water trying to enter the leak presses the sail against the planking, forcing the grease, wool, etc., into the hole, thus preventing the ingress of water to a great extent.

A "Tingle."

Where the hole is confined to one plank, and is of small dimensions, it may be permanently repaired at once if there are a few tools and some wood and screws in the boat. A "tingle" is a patch of wood or metal over a hole in a plank, and, if placed inside, should be made to fit the space between two timbers or ribs. It is then coated with white lead or thick paint and screwed down on the planking over the hole. An outside "tingle" can only be put on when the boat is ashore. It generally consists of a piece of sheet copper, with a layer of painted or tarred flannel, cotton, or even brown paper, between the metal and the plank. The edges of the "tingle" are securely fastened to the plank all round with closely-spaced copper tacks, and a repair of this sort will last for years if properly done.

Salvaging a Sunken Vessel.

In the foregoing cases it has been supposed that there has been material and opportunity to effect temporary repairs in time to save the boat from actually sinking, but in some cases this cannot be done, and the only thing then is to raise the boat as quickly as possible and get her ashore for repairs. If the boat has sunk in deep water, the advisability of trying to raise her is entirely a question of her value, but a boat sunk

in shallow water may easily be raised and recovered by means of a couple of boats of about her own size, provided ropes or chains can be passed under the sunken boat at low water and attached to the lifting boats on each side. Then, when the tide flows, the boat will be raised, and the three boats can be towed ashore at high water until the sunken boat again takes the ground. If this is in a place too far below high-water-mark for the execution of the necessary repairs, the lifting ropes or chains can be shortened and re-adjusted, the process being repeated until the boat is beached as high up as the draught of water will allow.

Refloating a Stranded Boat.

Run Aground.

One of the accidents which may easily happen to the most careful sailor is to run his boat ashore so hard that she will not come off again, although the engine is run full speed astern. In the event of such an unfortunate event occurring at, or about, high water, it is probable that the boat will have to remain until the top of the next high tide before she can be got off. As soon as the boat strikes the ground, reverse the propeller and go full speed astern. At the same time ascertain what part of the keel is on the ground, whether it is right forward, amidships, or aft. Probably it will be the bow only which is fast, in which case get all hands aft and roll the boat steadily from side to side, at the same time pushing off with the oars (if any), boat-hook, etc. This should immediately cause her to work her way off the bank. If she will not move at first, and the tide is flowing, it is only a matter of a few minutes before she comes off. If you have a dinghy and the boat is still disinclined to move, run out your anchor astern into deep water, and try to haul her off with that, at the same time placing any movable weights in the dinghy, together with all but two of your party, if there are several passengers on board, in order to lighten the stranded vessel. If the dinghy be too small to carry all the weights that can be removed, they should be put ashore by instalments, provided, of course, that the shore be close by and approachable. Otherwise, weights which will not suffer greatly may be thrown overboard, taking care to mark with a buoy the spot where they lie, and to lash together those which will float, attaching them by a line to a sinker to prevent them drifting away. But whatever action be taken it should be remembered that it should be done without delay; a very few minutes may make all the difference between getting off and sticking harder.

Left by the Tide.

If a boat runs really hard aground on a falling tide, there is often little or no chance of getting off before the tide leaves her, although the foregoing directions may, with luck, get her off. Once the tide begins to fall, and the boat shows an inclination to lie over a bit, lose no time in trimming all loose weights towards the side in which you wish the boat to lie. If she is ashore on the edge of a steep bank, it is of the utmost importance that she should take a list (or heel) towards the bank, otherwise she might easily fill up and fail to rise when the next tide commences to flow round her. The same rule will apply to the case where the boat may be exposed to a small breaking sea just before she floats, and she should therefore be listed towards the shore in any case.

Difficult Cases.

When the boat has grounded about high water, it will probably be advisable to lighten her of all movable weights, and, if you have no winch or tackle to heave her off with, it will be as well to borrow a small tackle or "Handy Billy," to get more strain on your cable than you could by hand. A good sized anchor will probably be required for this work, so if the boat's anchor is only a small one you must borrow one for the job. It may be that you have been unlucky enough to get your boat beneaped—that is to say, she has got ashore at the top of high water at or about the top of the spring tides, and the following tides will each be lower than the one before, until the lowest neap tide, after which the height of each high tide will increase until the top of the next spring tides. As these spring tides are a fortnight apart, it is not a cheerful matter to be beneaped if your boat is large.

Digging Out.

When a boat has got beneaped and you cannot afford to wait until the next spring tides, there is only one thing to be done to get her off, and that is to dig her out. This means digging a dock all round and under the boat, deep enough to ensure her floating on the next high water; probably a foot or two extra depth will be ample. A channel of the same depth as the dock and as wide as the boat must also be cut from the dock to the deeper water; the depth of the channel will, of course, decrease from the dock to the deeper water until it dies out to nothing; it should also be deepest in the centre to take the boat's keel. The course of the channel, if of considerable length, should be marked with a few sticks, long enough to show above the water at high tide, to guide you when hauling her out with the anchor, which must of course be laid out in a straight line with the centre of the channel. The boat, after all movable weights have been taken out of her, will be ready to be hauled out as soon as she floats in the dock. Always remember that rolling a boat when she is ashore, but waterborne, will help her very materially to work a channel for herself.

Knots and Splices.

Everyone who has anything to do with boats of any sort should learn a few of the simpler knots in common use for making a rope fast to a ring or post, or for joining one piece of rope to another. The novice usually makes a boat fast to a post by taking innumerable turns of the boat's head-fast or "painter" round the post, and then finally omitting to make a secure knot.

The Reef Knot.

The reef knot (Fig. 1) is a very simple knot to make; the illustrations show the distinction between it and the granny (Fig. 2), the difference being that both ends of each rope come out

Fig. 1.—Reef knot.

together on the loop of the other, whereas in the granny the ends come out upon different sides of the loop. There are two knots in common use, either of which will do to make a rope fast to a ring or a post; these are the bowline

Fig. 2.—Granny knot.

and two half-hitches; the former is the more seamanlike method, as it is not so likely to jam as the two half-hitches, while it is even more secure.

The Bowline.

This knot is made in the following manner. Pass the end of the rope through the ring or round the post, then take the standing part of the rope in your left hand, the ring or post being next to you and the end of the rope in your *right* hand; lay the end over the standing part and

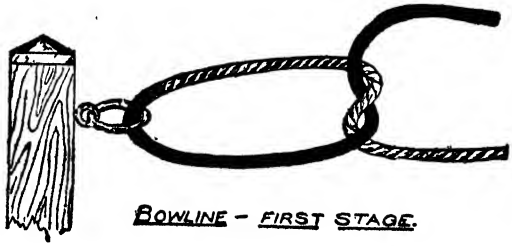


Fig. 3.

make an overhand knot as if you were going to make a reef knot (Fig. 3). Now capsize the knot until it becomes a half-hitch in the standing part on the striped end (Fig. 4). The end

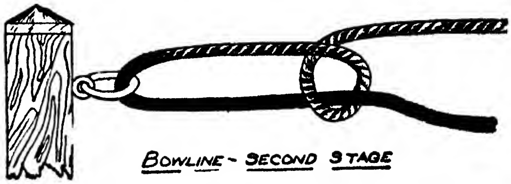


Fig. 4.

must now be passed behind and round the standing part away from the ring, and back *down* through the same half-hitch. The knot may then be pulled tight into the form shown in Fig. 5. Another and slower, but perhaps simpler method of making a bowline is to make a loop (Fig. 6) in the standing part, pass the end through the ring, *up* through the loop (Fig. 4), behind and round the standing part and down through the loop again as before, but care must

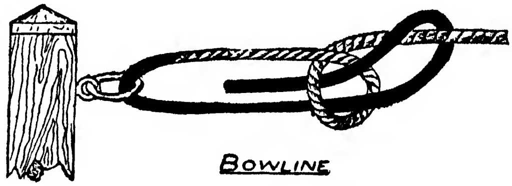


Fig. 5.

be taken that the loop on the standing part is made so that the part which goes through the ring comes above the standing part. Should the loop be made with this part underneath the standing part on top, then the end after passing through the ring must pass *down* through the loop, over and in front of the standing part and back underneath, coming *up* through the loop again; in fact it is exactly the same as before but the other way up. In most cases the standing part has been shown white and the end black, to distinguish them.

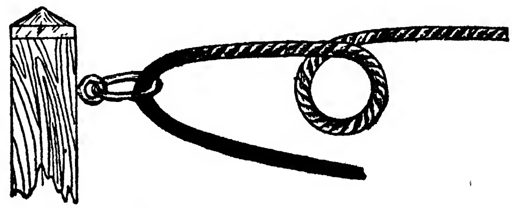


Fig. 6.—An alternative.

Two Half-hitches.

This is undoubtedly the quickest and simplest way of making a rope fast, and it is quite secure

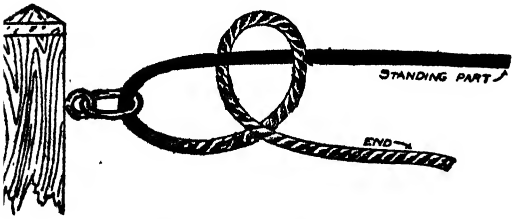


Fig. 7.—One half-hitch.

if properly done, but if too much strain be put on it it may join and cause a lot of trouble before it can be undone. To make this knot, pass the end of the rope through the ring as before, then round the standing part and up through its own bight or loop (Fig. 7). Now pass the end round the standing part once more and up through the

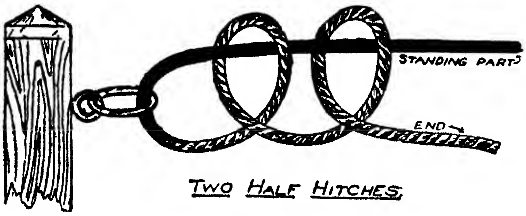


Fig. 8.

second loop (Fig. 8). In this knot the standing part always remains straight from the boat to the ring, while both the turns are taken entirely with the end.

Round Turn and Two Half-hitches.

A better knot for attaching a rope to a ring than the two half-hitches described is made by taking the rope *twice* through the ring instead of once before making the two half-hitches (Fig. 9). This is not so likely to jam, and permits of a good strain being put on the rope in the act of making it fast, which cannot be done with the bowline, and is liable to jam the two half-hitches.

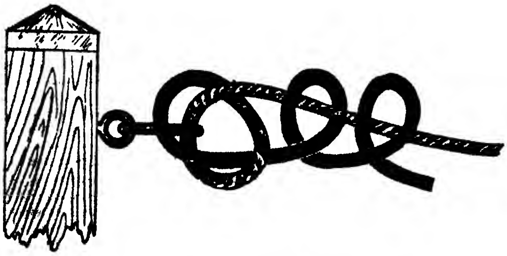


Fig. 9.—Round turn and two half-hitches.

Fisherman's Bend.

The fisherman's bend (Fig. 10) is usually employed for attaching a rope cable to an anchor in

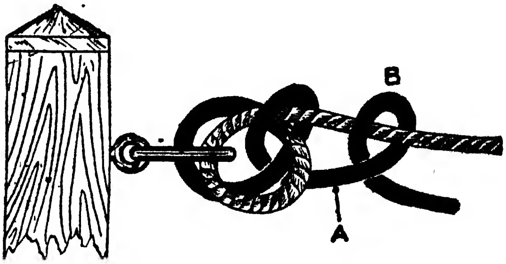


Fig. 10.—Fisherman's bend.

small boats; it is made by passing the rope twice through the ring and then passing the end through *both* loops. The knot, therefore, is complete at A, but for extra security the end is either seized (or lashed with small line) to the standing part, or a half-hitch is made round it as shown at B. The latter is the quickest method and most secure, but it is not quite so neat as the seizing.

Cow Hitch.

There is one other way of attaching a rope to a ring, which is frequently employed by landsmen, and that is the "cow" hitch (Fig. 11). In this case the end is simply tied to an overhand knot round the standing part; it is a most unseamanlike knot, as it is liable to jam and also

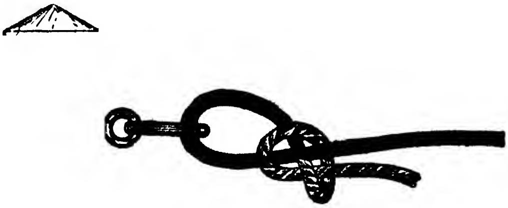


Fig. 11.—Cow hitch.

to slip, while it is at all times difficult to unfasten.

Fastening Ropes to Spars or Larger Ropes.

Most of the previous knots have been made for the purpose of attaching the end of a rope to a ring or round a vertical post to make the boat fast, etc.; but in the next series the knots are designed for making a rope fast to a spar, rail, or larger rope, which may be horizontal or in any other position, and on which the strain may come in the direction of the length of such spar. etc., in such a manner that it is important that the knot should not be able to slip *sideways* along it.

Timber Hitch.

The simplest of these knots is the timber hitch (Fig. 12), which is formed by taking a half hitch round the spar and twisting the end once more

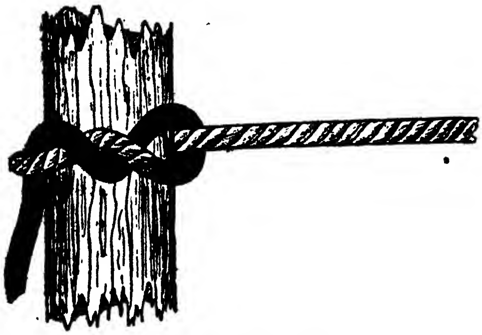


Fig. 12.—Timber hitch.

round its own part, instead of taking another half-hitch round the standing part. This knot is only satisfactory when it is made round a spar of considerably greater diameter than the rope, and so long as the strain is steady on the rope after the knot is made, as it is liable to come adrift if the rope is new and the strain intermittent. Another objection is that it cannot be made while there is a strain on the rope. It is, however, equally good for either side or direct strains, and it is very easy to make a cast off. The timber hitch is usually employed to attach a rope to the end of a spar or baulk of timber which has to be hauled over the ground, especially in the direction of its length, and for towing purposes. In the latter case, unless the tow is only for a short distance, a half-hitch might be used on the spar in addition to the timber hitch as an extra security .

Blackwall Hitch.

This is the simplest of all hitches, and is used to attach the end of a rope to a hook where the load is steady and fairly heavy. It is formed by passing the end of the rope over the middle of the hook, round it, and back over the hook, but *under* its own part, the weight on the first turn will then jam the end between it and the hook, so that it will never slip so long as there is a continuous strain.

Clove Hitch.

Where the strain is only sideways, or where *both* ends of the rope have to take equal strains, the clove hitch (Fig. 13) is one of the simplest and best knots. The illustration shows it so plainly that we need not describe how it is made, but we must warn beginners against a somewhat similar knot in which the two ends come out on the *same* side, instead of on *opposite* sides, as shown in the sketch. Remember that, in making a clove hitch, the end must always pass round the spar in the same direction, say, from left to right, in *both turns*, the first time passing under the standing part and the second time above the standing part, but under the last turn of its own part. This knot can be made

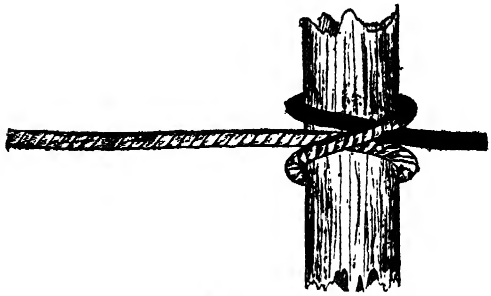


Fig. 13.—Clove hitch.

under strain and will not slip, no matter in what direction or on which end the strain may come. With a little practice a clove hitch can be made by giving the rope a couple of twists, forming a pair of loops, which are then dropped over the end of the spar and hauled taut.

Rolling Hitch.

Where a rope has to be made fast under a considerable strain to a spar or to another rope, and where it is desirable to increase rather than diminish the strain in the act of making it fast, the rolling hitch (Fig. 15) is the only suitable knot. To make this knot, take a single half-hitch round the spar or rope, as in Fig. 14,

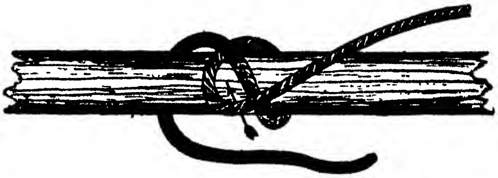


Fig. 14.—Rolling hitch, first stage.

keeping as much strain as possible on the rope (it is shown slack in the sketch to make the method clear); now take the end round the spar again and pass it up and under the standing part in the direction of the arrow, taking care that the second turn is *between* the first turn and the standing part, or as sailors term it, a *riding* turn; now take a third turn round the spar and pass the end up through its own bight or loop, making a half-hitch *outside* the first two turns, as shown in Fig. 15. It will be found that in

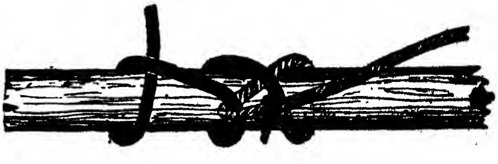


Fig. 15.—Rolling hitch.

passing the second or riding turn and pulling it tight *away* from the direction of the strain on the standing part that the latter is hauled bodily along the spar, etc., for the distance required to let the riding turn lie alongside the first turn, thus tightening the rope by that amount. The half-hitch then secures the whole knot. If a rope is passed through a ring and a rolling hitch made with the end on the main part of the rope it can not only be made fast under strain, but the hitch can be made to slide along the rope by removing the strain to a slight extent and pushing it along with the hand. This will allow the rope to be tightened or slacked at will, as in the case of tent ropes or boats' mooring warps when alongside a wharf or dock.

Joining the Ends of Two Ropes.

The common bend (Fig. 16) is the simplest method of joining two ropes. The end of one rope is doubled back on itself, and the other rope

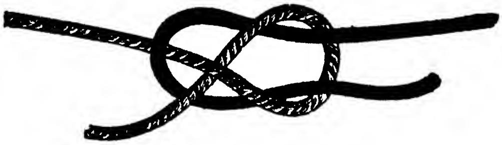


Fig. 16.—A common bend.

is brought up through the loop, round and under both parts and back over both parts of the loop, but under its own standing part. In making this bend be careful to hold the two parts of the (black) loop together until the knot is jammed tightly, as if any strain were to come on this black rope before the knot was secure it would unreeve itself through the other parts. To make an absolutely secure bend it is safer to make a bowline on the black rope, instead of simply doubling the end together.

Topsail Sheet Bend.

When the end of a rope has to be made fast to the bight (or middle) of another rope or to the cringle (or eyelet) in the clew of a sail, and the strain is intermittent, it is possible that the

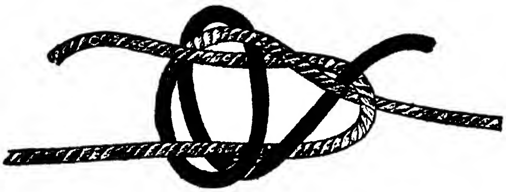


Fig. 17.—Topsail sheet bend.

common bend might shake loose unless it be very carefully jammed. In this case, a second turn is taken round the two parts of the loop and under the standing part, forming a topsail sheet bend (Fig. 17). This is particularly useful where the two parts of the loop to which the other rope is bent are liable to be pulled apart, as in this case the common bend would be capsized and come adrift.

Splicing and Whipping.

An eye in the end of a rope is frequently required on all sorts of boats, and on motor boats it is useful for the ends of head and stern mooring lines which are usually attached to the mooring bollards or to rings on the bow and stern of the boat. We would never advise splicing a painter or head fast into the ring in the bow of a boat, it is far better to make a long eye-splice in the rope and pass both parts of the eye through the ring and then pass the end of the rope through its own eye. This allows the rope to be detached from the ring at any time without cutting the eye.

The Eye-splice.

To make an eye-splice, unlay (or untwist) the strands for about five inches at the end of the rope in which it is intended to splice an eye.

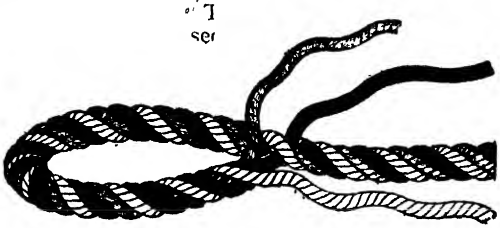


Fig. 18.—Eye-splice, first stage.

Double the end over to form an eye of the required size, so that the enlarged portion overlaps the standing part of the rope at the point where the splice is to start (Fig. 18).

Now open the lay (or twist) of the standing part of the rope by raising the middle strand (shown white) with a marline-spike. Then lay the untwisted ends over it, so that the under end (shaded) lies across the standing part and *away* from you, the upper and nearest (white) strand *towards* you, and the third or middle strand (black) right on top of the standing part. This centre (black) strand must now be tucked

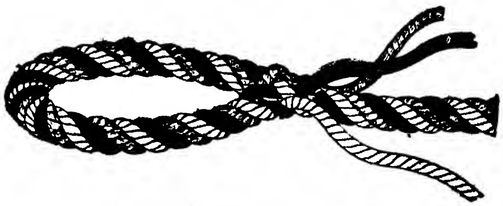


Fig 19.—Eye-splice, second stage.

under the raised (white) strand and pulled closely into place, as shown in the first sketch.

The under and further (shaded) strand must now be passed *over* the white strand under which the centre strand has already been tucked, and

it must then be tucked *under* the next (shaded) strand of the standing part (Fig. 19). The nearest and upper (white) strand being tucked under the third (black) strand of the standing part, so that all three strands of the end are under different strands of the standing part and all pointing *away from you and towards the right* if it is ordinary right-handed rope, or away from you but towards the left if the rope is left-handed. All the three strands should now be pulled gently towards the right until the two parts of the rope are closely united (Fig. 19). Once you have the three strands of the end passed under three different strands of the standing part, all you have to do to complete the splice is to continue passing each strand *over* the next strand to that which it has last been tucked under (always going over a strand) and *under* the next strand until each strand has been tucked under three times No two strands must be tucked under the same part unless there is another strand going *over* it between them. A splice may be tapered, so that the extra thickness caused by the interlacing ends will die away into the same thickness as the rest of the rope. To do this, after the strands have been tucked twice, they must be unravelled into yarns (six to each strand as a rule in small rope), these yarns must then be divided, say, into three parts, and only two-thirds of the yarns tucked under the next strand, half the remainder being again tucked: making two tucks with whole strands, a third tuck with two-thirds strands, and a fourth and final tuck with one-third strands. When the splice is complete and all strands hauled close, it should be placed on the floor and rolled under the foot, or lightly beaten with a mallet until all parts are forced down as smooth as possible, the ends may be then cut off about half an inch clear of the rope.

A Simple Method of Wire Splicing.

To splice an eye in wire rope whip the rope at the point to which it is necessary to unlay the strands for splicing; also whipping the end of each of the six strands. The correct method of splicing six-strand rope is rather difficult to describe, but it is simple enough if we take the six strands in pairs and treat them as three strands, tucking *two* strands under *two* for the first tuck, then for the second tuck take the farthest strand of each pair, tuck it over *two* and under *one*. The neared strand of each pair being taken over *one* and under one, this will bring each of the six strands out under a different strand and they will then follow on singly. To taper, drop one strand at the second tuck, one at the third, and so on.

The Short Splice.

Although the eye-splice already described is the simplest form for the beginner to learn, the short splice is really the one which best fulfils the true object of a splice in the ordinary sense of the word, i.e., joining two ropes together so that each becomes part of the other without a knot being used. In short splice both ends must be inlayed; they are then interlaced so that there is always one end of each rope between two ends of the other. When they have been pushed

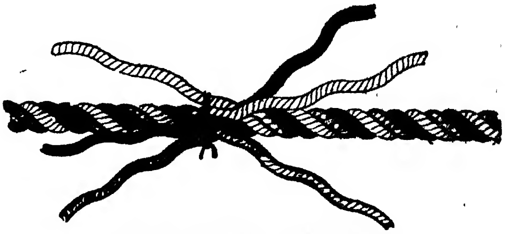


Fig. 20.—Short splice, first stage.

closely together they should be prevented from altering their position by a tight lashing over the three ends of one rope, and the standing part of the other (Fig. 20). This portion should be firmly held in the left hand, and a strand (shaded) of the rope on the right being raised with the spike; an end of the rope on the left (white) should be taken *over* the (white) strand before, and under the raised (shaded) strand. The next strand of the rope (shaded) must now pass *over* a strand of the rope (black), and *under*

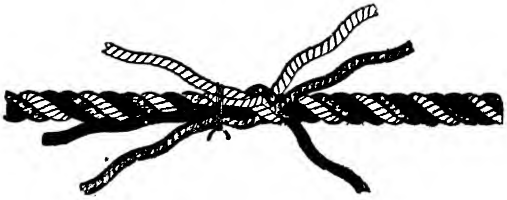


Fig. 21.—Short splice, second stage.

the strand (white) over which the first strand passed. The third strand (black) of the rope will then pass *over* the strand (shaded) of the rope *under* which the first strand (white) of the same rope passed. The result will now be that each strand is over one and under one of the other rope, all three strands of the rope coming out from under different strands of the rope (white under shaded, grey under white, and black under black)—Fig. 21. The next thing is to turn the rope round, so that what was originally

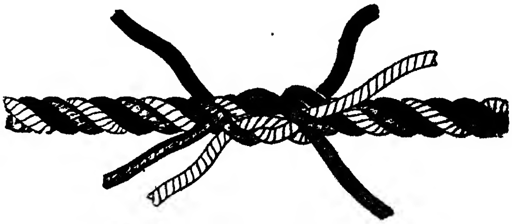


Fig. 22.—Short splice, third stage.

the rope on the right now becomes the one on the left; cut the lashing and tuck the new ends

as before (white over white and under shaded, shaded over black and under white, and black over shaded and under black)—Fig. 22. Each rope will now have its ends tucked *once* under the lay of the other rope, and the process should be repeated, with both sets of ends making two sets of tucks, or four in all. The ends can then be tapered as already described for the eye-splice if desired.

Whipping and Serving.

To prevent the end of a rope from unravelling, it is usual to bind it tightly with fine twine, which is called whipping the end. To do this, take a piece of waxed or tarred whipping or sewing twine and, holding the end of the rope in the left hand, nip the end of the twine under

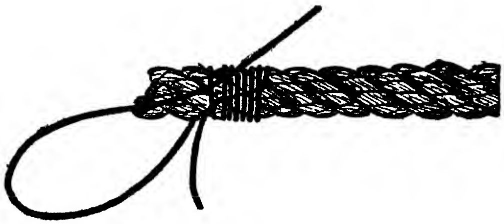


Fig. 23.—Whipping, first stage.

the left thumb on the rope, while a turn of the twine is taken round the rope over the end to jam it in place. The twine is now wound as tightly as possible round the rope and over its own end for five or six turns. The end is then turned back over these turns towards the right, and the rope is transferred to the right hand, which again nips the end under the thumb. The other end of the twine is now laid across the turns parallel to the first end, and the

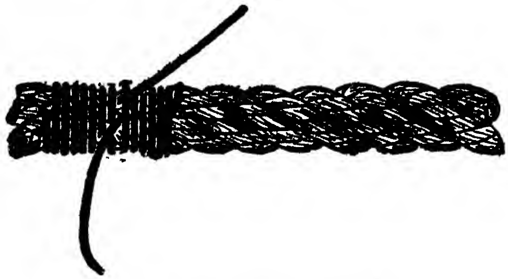


Fig. 24.—Whipping, second stage.

loop so formed is then wound round the rope's end and over its own end (Fig. 23) for another five or six turns, the end being then pulled tight, the two ends coming out in the centre, but in opposite directions (Fig. 24). For greater security these ends may be tied together in a reef-knot if required.

Serving.

It is usual to cover a splice with "marline" or small tarred line, which is put on in a similar manner to whipping, except that it is hove on taut with a serving mallet if one is obtainable. To serve an eye-splice, serve the rope for a distance equal to the circumference of the eye before the splice is made, then complete the splice and serve over it, starting from the eye and finishing at the end of the splice. Of course, in serving, the two ends of the marline or twine do not come out at the same place as with a whipping, but the commencement and finish are done in just the same manner by passing half-a-dozen turns over the end, which is then pulled tight. If it is in the centre of a rope, so that in finishing the loop cannot be passed over the end, the final turns must be taken over the finger or a marline-spike, and the end passed under them before the spike or finger is withdrawn, these turns being afterwards hauled taut one at a time.

The Spanish Whipping.

It is frequently necessary to secure the end of a rope from unlaying, when no whipping twine is available, and this may be done by working a Spanish whipping on the end, which is practically splicing the unlayed end into itself, forming a sort of club end, with the strands pointing back along the rope. The ends are first unlayed as for an eye-splice, but instead of making an eye, one strand (shaded) is bent back on itself, forming a loop, the next strand (black) is passed over the end of the first strand and also doubled back on the rope (Fig. 25). The third (white) strand is then passed over the end of the second

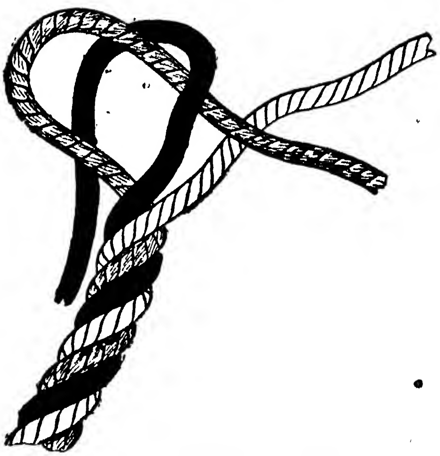


Fig. 25.—Spanish Whipping, first stage.

(black) strand and back through the loop of the first (shaded) strand, all three strands being turned back along the rope, and each under a different strand (Fig. 26). The three strands are now hauled taut and passed over and under the strands of the standing part (white under shaded, over black and under white; shaded under black, over white and under shaded, and black under white, over shaded and under black)

Fig. 27. This is repeated until each end is tucked three times. A sort of taper may be

Fig. 26.—Spanish whipping, second stage.

made of this whipping and of a splice by omitting to tuck one of the strands each time *after*

Fig. 27.—Spanish whipping, third stage.

the first two tucks until one strand only is tucked the last time.

The Single Wall.

Among many knots which are ornamental rather than useful is the man-rope knot used on the ends of the white cotton man-ropes at the gangway of large yachts, or for any purpose where an ornamental knot is wanted.

The first stage of the man-rope knot is shown in Fig. 28, and is termed a single wall. It is formed in much the same way as the first part of the Spanish whipping already described; but instead of each end passing over another end down alongside the rope, they are taken round another end and *up* away from the rope as shown in Fig. 28. Grey is first formed into a loop with the end *up* between black and white. Black

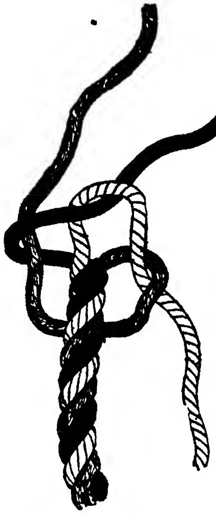


Fig. 28.—Single wall. Fig. 29.—Wall and Crown.

is then taken round grey and *up* between white and grey, while white is taken round black and up through the loop of grey, the whole being then pulled gently into place until all the turns are even but not tight.

The Wall and Crown.

The next stage is precisely the *same* as the commencement of the Spanish whipping. Grey is formed into a loop with the end *down* along

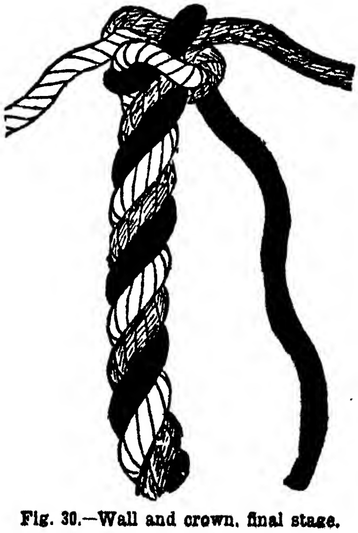


Fig. 30.—Wall and crown, final stage.

the rope between black and white. Black is taken over grey and *down* between white and grey, and white is taken over black and through the loop of grey *down* along along the rope, as with the others. The three ends now come out at the sides of the knot between the two parts, which together are called a wall and crown (Fig. 29). This in itself is a pretty knot, but it has the great disadvantage of easily working loose and coming to pieces unless it is made of tarred rope and hove up tight as shown in Fig. 30.

The Man-rope Knot.

To make the wall and crown into a man-rope knot all that is necessary is to keep the first knot slack and follow the strands round, under and over, until each strand has gone round the knot twice. The ends finally go down the centre of the knot and come out between the strands of the rope underneath the knot (Fig. 31), where they are cut off after the knot is finished. As the knot has been made loosely it must be hauled taut before it is finished and the ends cut off. This is easily done by inserting the point of the marlin-spike under, say, the black strand at the root of the knot (the lower of the two black strands), and pulling it tight away from the standing part, then do the same thing where this strand next appears, following it round the knot until all the slack can be pulled out by the end of the strand under the knot. The other two strands must also be tightened in the same way, and, if necessary, all three should be gone over again to get the knot tight and symmetrical, with an equal strain on every part of all the three strands, which may then be cut off as close as possible.

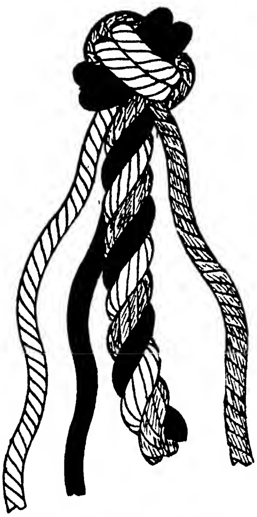


Fig. 31.—Man-rope knot.

This knot can be made equally easily in either three or four-stranded rope, and is a very ornamental knot.

Splicing Four-stranded Rope.

All the directions for making a short splice, or an eye-splice, have been for the common three-stranded rope, with the exception of the short note on splicing an eye in six-stranded wire rope, which can be treated as three-stranded rope, with slight modifications. There is, however, another make of rope in the best qualities of yacht Manila which has four strands. In making a short splice it is of no consequence whether the rope has three, four, six, or any number of strands, provided both parts are the same, but for an eye-splice four-stranded rope is tucked for the first time in a different manner to three-stranded. Instead of having one centre strand to start with, we have two, the farther one of which is tucked as in three-stranded rope, under a strand of the standing part so that it comes out *away* from the hand, while the nearer of the two is tucked in at the *same* place but *down* under the next strand nearer to the operator and comes out *towards* him instead of away from him as all the others do. The farthest and nearest strands are tucked exactly the same as if the rope was three-stranded, so that the nearest strand passes under the same strand of the standing part as the nearer of the two middle strands, but away from you, while the other is towards you. They are then tucked over one and under one as usual, and tapered until the splice is complete.

Pilotage and Coastal Cruising.

Pilotage.

Everyone who goes in for boating in any form on sea or river should endeavour to acquire a rudimentary knowledge of the fascinating science of pilotage. In other words, all boat owners should know by the look of the water when to expect shoals or strong eddy tides, also where to go to avoid the full strength of a foul tide if forced to run against it, not that this knowledge should ever be allowed to supersede the proper use of the lead line.

Shallows.

There are several indications of shoal water, plain enough to experienced eyes, and in clear sea water it is simple enough for the merest novice to see by the lighter colour of the water in the case of sandy bottoms, or by the sight of waving grounds of weed on rocky ground, when he is getting into very shallow water, say 6ft. or 8ft. in depth, and this, combined with a sharp look-out, should be enough to keep him clear of the ground in fine weather. In tidal waters these shallows are clearly marked by sharp lines of ripples even on a calm day, and often by a muddy colour.

Isolated Rocks.

When running along a rocky part of the coast one of the worst dangers to be avoided is the occasional isolated rock, perhaps just submerged at low water and quite invisible at other states of the tide except when the weather is bad and its presence is indicated by broken water. Most of these rocks, if of any size, are marked on the charts and mentioned very fully

in the sailing directions, but there are plenty of small ones close in shore which are not marked at all, and these are just the ones to pick up the man in the small boat if he be a stranger.

What to Avoid at Sea.

Keep clear of solitary patches of breaking waves when the rest of the sea is only rolling without breaking; also avoid close quarters with any appearance of an eddy on a calm day. Both these indicate submerged rocks or lumps of hard ground just below the surface. Where there is no tide to speak of, and a perfectly smooth sea, it is very difficult to detect a submerged rock a couple of feet below the surface until one is on it.

Stream Signs.

Where there are strong tidal streams, such as one meets with in the mouth of large rivers, there are clearly marked surface indications which will not only tell the experienced pilot when the water is shoaling, but also show the various eddies and slacks to be worked when proceeding against the stream. To a novice many of the surface ripples appear to be exactly the same, whereas he should know that while *transverse* ripples across the run of the stream almost invariably mean a ledge or shoal, a long line of little ripples or wavelets jumping up in all directions, but keeping generally in the line in which the stream is running, merely mean the dividing line between the full strength of the stream and the side eddy. When there is any wind against the stream the roughest bits of water indicate the strongest stream; in many cases the heart of the tide, as it is called, is clearly defined by steep, short, transverse waves extending right across, while the slack water at the sides is comparatively smooth.

Tide Races.

Any motor yacht or boat going round a headland should keep a sharp look-out for tide races, and should either keep close in shore if there are no outlying rocks to pick her up, or go far enough out to sea to get beyond the influence of the race, unless the rounding can be made at high water or low water slack tides.

Ebb Tide Out of Harbours.

Beware of the rush of the ebb tide out of harbours. When the ebb tide runs out with the wind blowing in from the sea, a fearful sea is knocked up either just between the piers or else a little distance outside, and many a small boat has been swamped within a few yards of the entrance owing to the rush of tide meeting the resistance of the sea and wind in the entrance. Even on a calm day great care should be taken when entering or leaving harbours of this description except at high water. Another thing to beware of in many of these harbours is the set of the tide *across* the entrance.

Shoals.

The general characteristics which indicate the position of shoals and eddies are much the same in most rivers, although each one may have additional local peculiarities of its own, caused by some special conformation of the bottom or sides. It may be taken as an axiom that the swifter the current the plainer will be the indications of both shoals and eddies for any given depth of water. Consequently, although the dangers are much greater on a river with strong tides or currents than they are on a more sluggish stream, yet they are much more easily seen and avoided on the former than they are on the latter, especially if, as is so often the case, the shoals in the slow-running river are smooth mudbanks without any abrupt alterations of depth to indicate their presence by the formation of surface eddies or ripples.

Currents in a River.

The most important thing to be remembered with all rivers is the direction of the run of the main stream as affected by the bends of the river. Taking the ebb tide in the lower reaches as the strongest and most important state of the stream (going ashore on the ebb means staying there until the flood tide refloats you), we will suppose that there is a sharp bend in the river round a point. The point itself may be "steep to," or with deep water close in shore and a steep angle to the bank. The main strength of the stream will probably be fairly close in to the point by which it will be deflected, and will then run short off in a more or less straight line towards the opposite shore as it curves round.

Eddies.

Immediately below the point down stream there will be a strong eddy in which the current will be running up river, or against the main direction of the stream itself. The boundary between the main stream and the eddy will, as a rule, be clearly marked by a sharp line of disturbed water, which may be only a confused jumble of ripples on a calm day, or, if there is much wind, it may become a very fair imitation of a cauldron of boiling water. In any weather this tide rip or "scrimmage," as it is called, is almost invariably a confused streak of water in which the waves or ripples run from all directions. The centre of the main stream, if the wind is against it, will probably be much rougher than the "scrimmage," but here the waves will be fairly regular and at right angles to the run of the tide. With the wind in the same direction as the stream, however, the centre need not necessarily be so rough as the "scrimmage" at the junction of stream and eddy, but, as a rule, rough water in the centre of a river indicates tide. It must, however, be borne in mind that in a river, as it is elsewhere, a rough patch with short transverse waves, especially if the latter be stationary, may indicate a shoal or bar across the run of the current.

Similar stationary transverse waves are usually to be met with just below the arches of many of the old stone bridges, at which point there is frequently a series of short waves so steep as to be dangerous to a very small boat with low freeboard.

Direction of Stream.

Having dealt with the surface indications, which show the run of the stream and eddies, and which will practically be the same for all rivers with a current of over two miles an hour, no matter whether it is tidal or merely an ordinary fresh-water stream, we will now consider the probable direction of the stream as affected by the conformation of the river bed.

The reason why the stream runs its hardest sometimes on one side of the river and sometimes on the other, is because running water, like all other moving bodies, is immediately deflected on striking against a resisting surface placed at an angle with the direction of its flow. Let us suppose that the river is perfectly straight. Then the strongest part of the main stream will run down the centre of the river bed, with slacker water on each side close in to the banks. Now, suppose the channel takes a sudden bend to the right, and then continues in a straight line as before. The stream will continue on its original course past the bend until the left-hand bank deflects it. If the curve is very gentle, the deflection will be very gradual, but if it is a sharp turn, the stream will be thrown off below the bend, at an angle towards the right, until it strikes the bank and is again deflected towards the left. As water is not a solid body, the deflection is not perfect, and each time the stream strikes the bank it is deflected less than it was the time before, until it again runs down the centre parallel to the banks. The foregoing is the effect produced on the direction of the stream by a single bend in an otherwise straight channel, but it is much more common to find a river bending alternately to the right and left in a serpentine form. In this case, supposing the first bend to be to the right from a straight reach as before, then the stream, being deflected from the left bank below the first bend, strikes the right bank and is again deflected to the left, where there is another bend to the left this time. The stream therefore rushes close to the point forming the bend and strikes the right bank again as it curves round towards the left, and so on all down the river. It may be taken as a general rule that the strongest part of the stream is close to a point, and the strongest eddy is just below the same point, while a comparatively steady, but still strong, stream sweeps in round the opposite bend below the point.

How to Steer up Stream.

When coming up a river against the stream always keep close in to the bank below and on the same side as a point, as there you will find an eddy, which at first will be very wide, but with little difference in its direction to the main stream. As you approach the point which causes the eddy, you will find, if the tide is strong, that the width of the eddy from the bank is rapidly decreasing, but it is now a distinct stream running in the opposite direction to the main current, and increasing in strength as it narrows and the point is neared, until it suddenly ceases to exist, having been turned round into the main stream again. It is at the apex of the rough triangle formed by the bank below the point on the one hand, and the main stream on the other, that the roughest part of the "scrimmage" is found, and just abreast of the point the stream is at its narrowest as a rule. In a few cases, where the point is very prominent and the stream very strong, there will not only be an eddy, but even a second eddy inside the first and running slowly in the same direction as the tide. When a point is reached and the last of the eddy disappears, strike across for the opposite bank and work up close in shore until the next eddy is reached, repeating the process so long as the river continues to curve from right to left and from left to right alternately. If, however, it should go on turning, say, to the right, then the slackest water will usually be found along the inner side of the curve, in this case on the right bank. Coming down with the stream keep fairly in the centre where the channel is straight, but rather closer to the points at all bends unless they look shallow. It is as well to remember that where the eddy is below a point, there is frequently a flat and shallow place caused by the silt deposited by the eddy. In some cases, especially where the banks are of soft mud, a point may be very shallow and run off a long way even above the bend. As a rule, there is deep water close in to the bank on the outer side of a curve, and wherever the stream runs strongest.

Rigs of Various Vessels.

The following is a short illustrated description of the various kinds of vessel to be met with when cruising round our coasts and about the larger ports.

That owners should be able to give a name to any rig they may chance to come across is very desirable, for nothing calls forth the ridicule of yachting men more quickly than ignorance of technicalities of this kind.

It will be impossible to give full details of every sort of craft in the limited space at disposal, so we propose to take the principal varieties only, commencing with the ship.

The Ship.

In one sense, of course, all vessels are ships, but to a sailor the term ship, when used to describe a vessel's rig, invariably means a vessel

with three masts (or more in many modern vessels), square rigged on all her masts. That is to say, each mast is fitted with yards and square sails as shown in Fig. 1, which gives a rough outline of an ordinary three-masted ship,

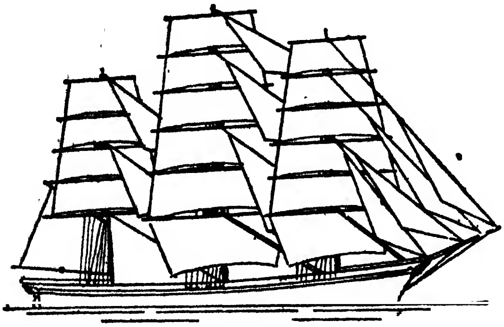


Fig. 1.—Three-masted ship.

while Fig. 2 shows a four-masted ship, and there are a few ships with as many as five masts, although such vessels are not common.

Names of Masts and Sails.

The names of the various spars and sails are, with a few exceptions, common to all classes of vessel, so a brief list of these terms may be of use to make the various descriptions as clear as possible. Starting from forward, the first spar is the bowsprit (pronounced bo-sprit). The side stays on this spar are termed bowsprit shrouds, and those underneath bob-stays. In addition to the single bowsprit, now almost universal, ships in former days were fitted with a second spar projecting beyond the bowsprit and called a jib-boom, and sometimes even with a flying jib-boom beyond this. The forward mast of all is the fore mast, then comes the main mast, and, in a four-masted ship, the after main mast, and last of all the mizzen mast. All these masts as a rule consist of three parts in modern ships, lower mast, top mast, with top gallant mast and royal mast in one spar above all. Many ships nowadays carry nothing above the top gallant sails (pronounced t'gal'nt's'l), but the old tea clippers had separate royal masts in some cases. The square sails are named as follows from the deck upwards, fore sail or fore course, lower fore top sail, upper fore top sail, lower fore top gallant sail, upper fore top gallant sail and fore royal. The head sails from the fore mast to the bowsprit are the fore topmast stay sail, inner jib, outer jib, and the flying jib outside all The sails on the other masts have the same names except that the name of the mast is altered as required. There is only one exception to this rule, and that is the lowest square sail on a ship's mizzen mast which, instead of being called a mizzen sail or mizzen course, is known as the cross-jack (cro'jack), this sail, which is not shown here, is not so much used as the other lower sails, as immediately behind it on the same mast is a gaff sail called the spanker, over which is set the gaff top sail. The fore and aft sails between the masts are top mast, top gallant mast, and royal stay sails, named after their respective masts. The rigging consists of standing and running rigging, the former being used to support the masts and consisting of stays to hold the masts forward, lower, topmast, and top gallant shrouds, to hold the masts sideways, and back stays to hold them aft. The running rigging would make too long a list here, so we will merely take one sail, as all are fitted more or less the same. First we have the halyard to hoist the yard on the mast; this consists of two parts, the tye or single chain through a sheeve in the mast head to the yard, and the purchase from the other end of the tye to the deck consisting of two blocks, with several sheeves, according to the weight of the yard and sail.

The lifts go from the mast head to each yard arm (or outer end) to keep the yard level. The braces go from each yard arm to the deck, or to the mast immediately behind to turn the yard round from one side of the ship to the other. The sail itself is "bent" or fastened to the upper part of its yard to an iron rod or jack stay, and its lower corners or clews are hauled down and out to the ends of the yard beneath by chain sheets and hauled up to its own yard for stowing by clew lines, the middle or bunt of the sail being hauled up by bunt lines. On the lower sails the chain or rope holding down the lower corner of the sail on the side from which the wind comes is called the tack, while that on the outer side is the sheet. The head sails and stay sails have halyards, sheets, and

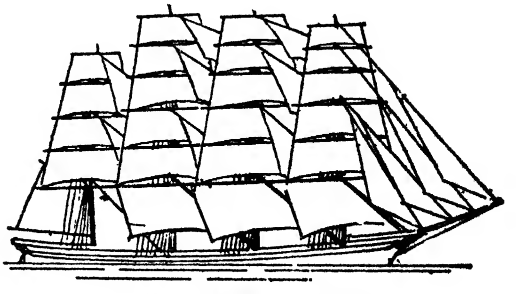


Fig. 2.—Four-masted ship.

downhauls, and the spanker has peak halyards, vangs (or guys) to steady the end of the gaff, and outhauls to haul the sail out on the gaff and boom and brails to gather it up to the mast.

The Barque.

The barque is merely a ship with the after mast fore and aft rigged without square sails or yards, and it, like the ship, may have any number of masts, three or four being the commonest (see Figs. 3 and 4). It is usually considered to be a handier rig than the ship,

especially for small vessels. There are several varieties of the barque rig, some having no square mainsail, and occasionally no square fore sail; all these are known as "Jackass" barques, and are mostly to be met with about the Mediterranean. If the masts are all in

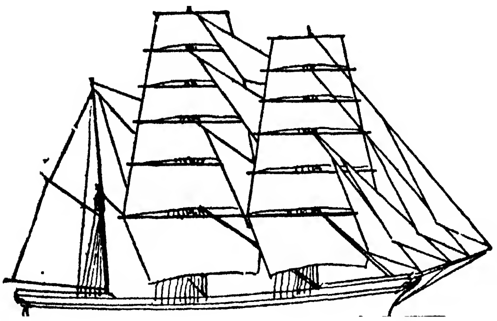


Fig. 3.—Three-masted barque.

one piece from deck to truck, they are then known as polaccre ships, barquesq, brigs, etc., but though this was a common rig in the early part of the last century, it is rarely seen now, and it was only used in small vessels. Any

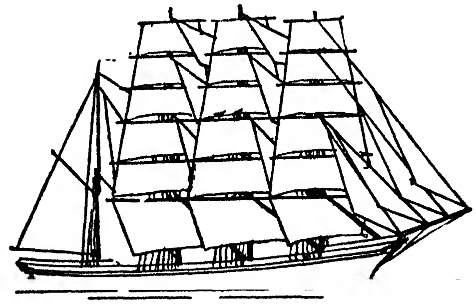


Fig. 4.—Four-masted barque.

departure from a regulation rig is usually known as a "Jackass" rig, no matter whether it be a barque, brig, or other rig.

The Barquentine.

Next in size to the ship and the barque comes the barquentine (Fig. 5), which is frequently confounded with the three-masted top sail schooner (Fig. 6). The difference between them lies entirely in the manner in which the fore mast is rigged and fitted. In the barquentine the fore mast consists of a lower mast, top mast, and top gallant mast, with fore sail or fore course, upper and lower fore top sails, single fore top gallant sail as a rule, and sometimes a fore royal. On the other hand the three-masted top sail schooner, although she is also square rigged on her fore mast, has only a fore mast with the fore top mast and top gallant mast in one; she has usually a fore and aft gaff sail and a fore stay sail, neither of which is used on vessels which are fully square rigged forward.

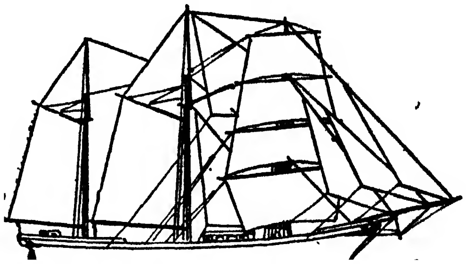


Fig. 5.—Barquentine.

Her square sails consist of an upper and lower fore top sail and a fore top gallant sail only as a rule, all her other sails being fore and aft. This, with the barquentine, is one of our com-

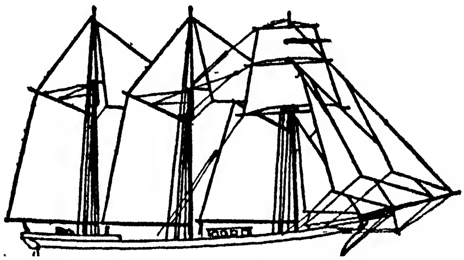


Fig. 6.—Three-masted topsail schooner.

monest coaster rigs for the larger class of vessels; in the States, however, the square top sails are generally omitted and the number of masts increased, in some cases up to seven even.

The Brig and the Brigantine.

These rigs are both two-masted vessels, and bear the same resemblance to one another as do the ship and the barque previously described; the difference consisting in this case, as in the

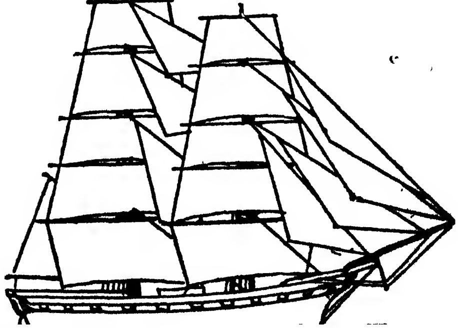


Fig. 7.—Brig.

larger vessels, in the after mast of the brig (Fig. 7) being square rigged as in the ship, while the after mast of the brigantine (Fig. 8) is fore and aft rigged as it is in the barque.

It will be noticed that the arrangement of the square sails and head sails is slightly different in some of the smaller vessels. The reason of

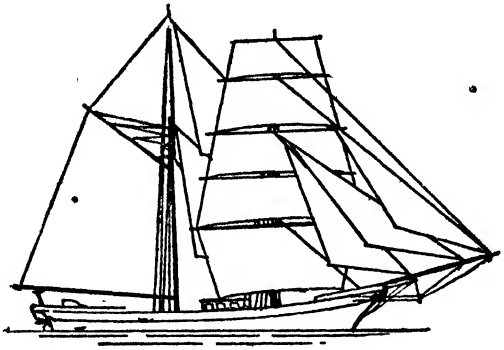


Fig. 8.—Brigantine.

this is that, in the first place, there are several ways of rigging these vessels, and, in the second place, small vessels never have double top gallant sails and frequently only single top sails, whereas in the larger vessels, in which the sails and spars are very heavy, double top sails are universal and double top gallant sails nearly so. The old vessels used single top sails and top gallant sails with all sorts of light sails, such as sky sails and moon sails, above the royals, to say nothing of various fancy sails on and under the bowsprit, among which was the "Jimmy Green." All these sails have gone out of fashion now except the studding sails (pronounced "stun-s'ls"), which are still used, and consist of small square sails set outside each of the ordinary square sails by means of stun-s'ls booms projecting beyond the yard arms. The sails were called fore top mast stun-s'ls, main t'gal'nt stun-s'ls, etc., according to the position of the sail.

Smaller Craft.

The vessels described hitherto have been principally ocean-going craft which would be engaged in long voyages to foreign ports all over the world, with the exception of the four last—viz., the barquentine (sometimes termed a three-masted brigantine), the three-masted schooner, the brig, and the brigantine. These four rigs are usually met with on small craft in the coasting trade, although many of them are also foreign-going vessels of from two to five or six hundred tons register. The other rigs mostly favoured among coasters are the topsail schooner (two masts), the ketch, and the Thames spritsail barge. The latter is essentially a Thames estuary trader, hailing from London, Rochester, Maldon, and Harwich, but Thames barges may be met with down Channel as far west as Plymouth, all along the French and Dutch coasts, and well up our east coast. They are wonderful sailers in the comparatively sheltered waters for which they are designed, being remarkably close-winded and splendidly handled, but they are by no means ideal craft at sea in bad weather. The list of vessels working on our coasts would not be complete without the fishing lugger (Fig. 9), which may be found wherever the herring and mackerel happen to be, from Land's End to the northern coast of Scotland. Their rig consists of a dipping lug on the fore mast (which has to be lowered and re-set on the other side of the mast every time the boat tacks) and a standing lug mizzen, frequently surmounted by a small top sail as shown. They are probably the finest sea boats on the coast, this form of sail being particularly good in bad weather, owing to its lifting qualities as com-

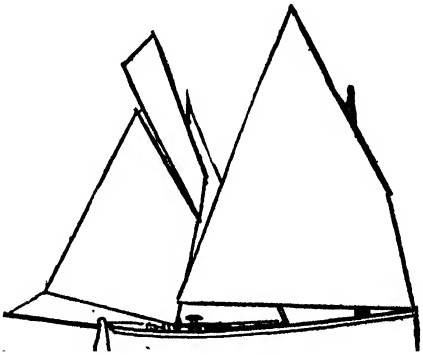


Fig. 9.—Lugger.

pared with the pressing effect of the gaff sail. The dipping lug has, however, one great drawback, as it requires a large and expert crew to lower and re-set it in tacking.

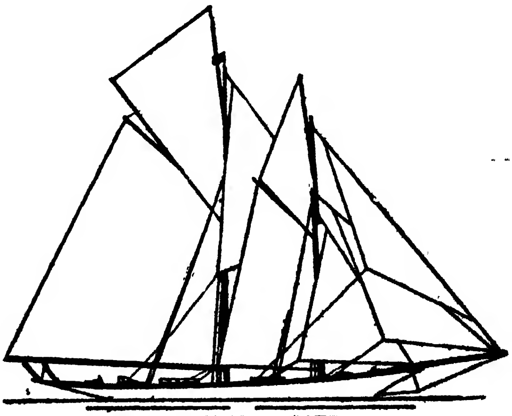


Fig. 10.—Schooner yacht.

Yachts.

The largest yachts are, of course, the full-powered steam vessels, which, like the mail boats and ocean tramp steamers of the mercantile marine, are now hardly rigged at all, a pair of naked pole masts being all that is considered necessary on most modern vessels, and even that small amount of rigging is more as a concession to old ideas than for any actual use. The largest of our sailing yachts are usually schooners (Fig. 10), and although most of them are cruisers pure and simple, there is of late years a decided tendency to revive the big racing schooner which was so common fifty years ago. The sketch shows a schooner which would be capable of a considerable amount of cruising although fitted with a regular racing rig, such a vessel, in fact, as "Meteor" or "Rainbow" (now "Hamburg"), both of which are well known as racers and also as having crossed the Atlantic. The ketch (Fig. 11) is purely a cruising rig, and it is probably the handiest for that purpose, for yachts of anything between 50 and 200 tons Y.M. For racing yachts of these dimensions the yawl (Fig. 12) and the cutter (Fig. 13) are the most popular rigs, the former being the handier of the two, while the latter is the best all-round rig for racers, although the long and unwieldy boom puts it quite out of the question for a cruiser of any considerable size. The smallest racers are usually lug-sloops (Fig. 14), but this rig is rarely used on boats of over 25ft. water line, as the sail is very unmanageable, if it exceeds 400 or 500 square feet area. However, on small boats there is little doubt but that it is the closest-winded rig in existence and very simple in gear and other details. A combination of the racing lug, as used on the Clyde and Solent, and the regular gaff mainsail is probably superior to either sail, as it is cut with a high peak like the lug, but instead of a yard slung in the middle it has a long gaff, with jaws round the mast, hoisted by a peak and throat halyard.

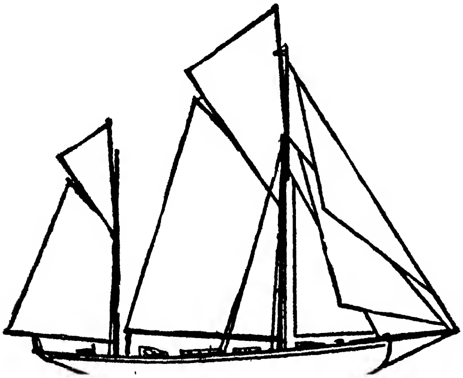


Fig. 11.—Ketch.

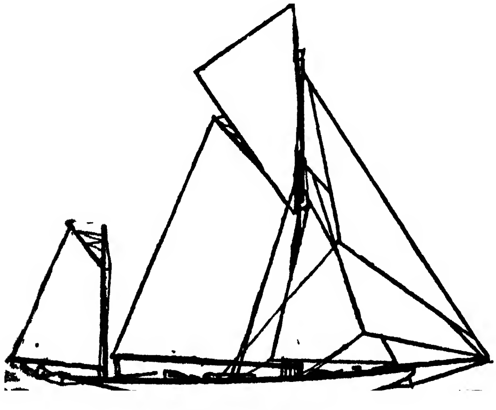


Fig. 12.—Yawl.

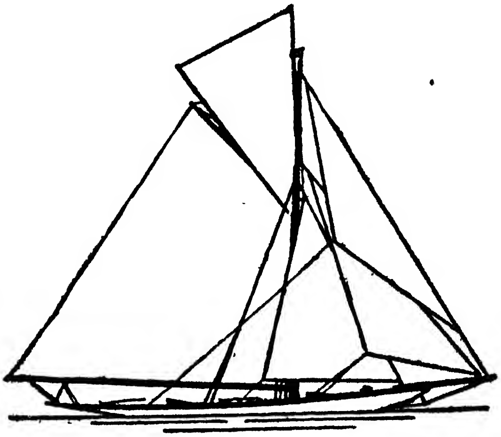


Fig. 13.—Cutter.

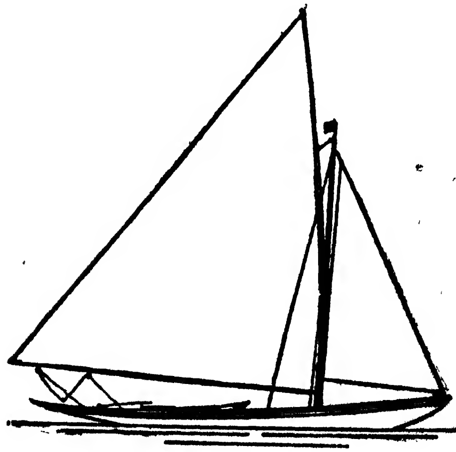


Fig. 14.—Lug-sloop.

DINGHIES.

One of the greatest trials of life to the owner of a small cruising yacht, no matter whether she be propelled by sail, steam, or motor, is the vexed question of the dinghy. Should he or should he not take a dinghy on a long cruise? If no dinghy be taken, the yacht has not the (literal) drawback of having to tow it if she be too small to carry it on board; but, on the other hand, it is often difficult to get ashore or aboard if there is no dinghy, shore boats being at times difficult to get, and nearly always expensive to use. Occasionally, on arriving at a strange anchorage late at night it will be found impossible to get a boat to go ashore in, and if all hands have had a wetting during the passage it is by no means a cheerful look-out if they have to spend the night aboard with everything wet through.

Of course, on a yacht of anything like 20 tons a proper wood dinghy can be carried on deck, but in the smaller craft such a deck-load will be a serious inconvenience, especially in bad weather. A boat on deck is perhaps not so troublesome on a motor yacht of considerable power as it would be on a sailing yacht or an auxiliary, which would have to trust principally to her sails for making a passage. On the motor yacht a large amount of deck space is not the necessity that it would be on a sailing vessel, as there are no sails to work; but, even so, if she be a small boat of 30 to 40 feet only, a dinghy on deck is an awful nuisance, and takes up a lot of room, unless she will fold up flat, as many do. Folding dinghies also have their own peculiar disadvantages. Some are as heavy or heavier than an ordinary dinghy of the same size; others are crank, and will turn a novice out into the cold and unfeeling ocean with surprising ease—usually to the joy of the spectators; while others, again, are very troublesome to open or close on the deck of a small vessel, where it is practically impossible to get round them.

Taking all these points into consideration, the best course is probably to carry an ordinary clench-built pine dinghy, even if only 8ft. long, if you can carry it on deck when making a passage. If your boat has no room for an ordinary dinghy, then use a folding boat, and stow it flat on the cabin top, or even in the cabin if it can be coaxed through the companion-way. If there is absolutely no room for even a folding boat aboard, don't be bothered with a dinghy at all on a long cruise, as you are sure to get her full of water or rolled over some time or other when towing in really bad weather, to say nothing of that engaging little habit dinghies have of jumping on the counter in a following sea.

The Points of a Dinghy.

Now as to the various points to be borne in mind when buying a dinghy. A good dinghy should be light but strong, with a very flat floor, hard bilges, and a full bow and stern, to get the maximum carrying capacity and stability. On no account have anything to do with a sharp-sterned dinghy (except where it is a necessity to enable the boat to be folded); they are reputed fine sea boats, but as a matter of fact they have nothing like the stability or carrying capacity of the ordinary square-sterned boats; nor are they a bit better in a sea; in fact, most of them are extremely crank, and require most careful handling.

The Berthon.

Of the various patterns of folding dinghies, the Berthon, Fig. 1, is the oldest and best known; it is also one of the strongest, but it is rather heavy. It is a good, serviceable boat,

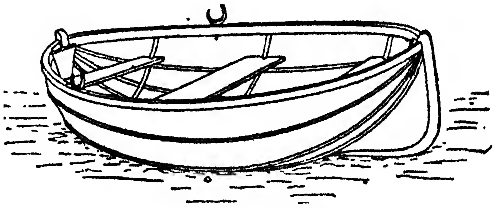


Fig. 1.–The Berthon.

and, having two skins of canvas with an air space between, will support the crew even when swamped; and if one skin be torn in beaching, etc., the inner skin would still enable the boat to be used.

The James.

A very similar boat is the James, Fig. 2. In this boat only one skin of canvas is used, and fewer wood battens to distend the sides when open. It is much lighter than the Berthon, and easy to repair if the canvas is pierced—a difficult operation in the case of a double-skinned boat; but, of course, if a hole is made in the canvas it will not support the crew.

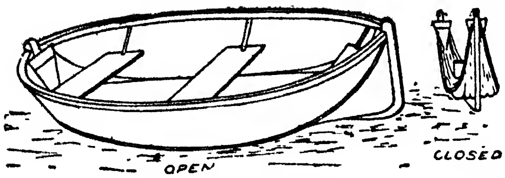


Fig. 2.—The James.

The Oxford.

The Oxford folding boat, Fig. 3, is on quite a different principle to the Berthon and James boats, in both of which the sides fold down alongside the stem, sternpost, and keel, while

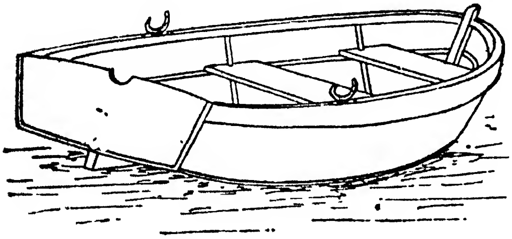


Fig. 3.—The Oxford.

in the Oxford boat the bottom is of wood and nearly flat, the transom and sides folding down on it when the inner stem and a stretching piece are removed. This is a very strong boat, but, like the Berthon, rather heavy. It is very suitable for use on a beach, and has great stability.

The Shell-bend.

The Shell-bend, Fig. 4, is a wooden boat, built of two diagonal skins, with canvas between and strong canvas joints along the angle of the bilge (or "chime," as it would be termed in a barge); the two sides and the bottom are elastic, and when the thwarts or seats are removed the

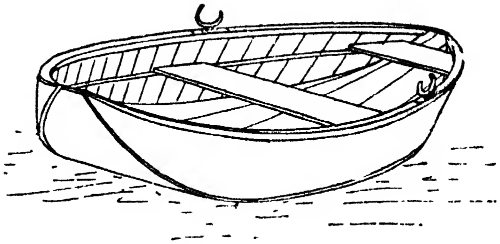
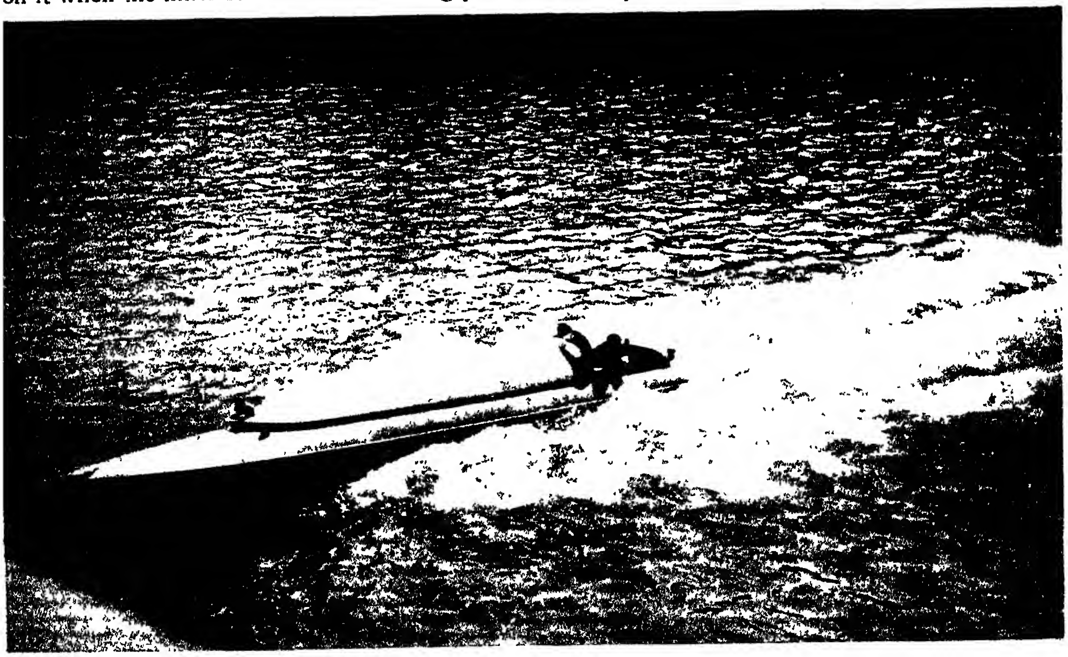


Fig. 4.- The Shell-bend.

sides may be folded down inwards on the bottom, and the whole stowed flat. These boats tow very well, and are very strong; they are also very useful to get over mud flats, as they can be pushed over the mud with ease when an ordinary boat could not be moved.



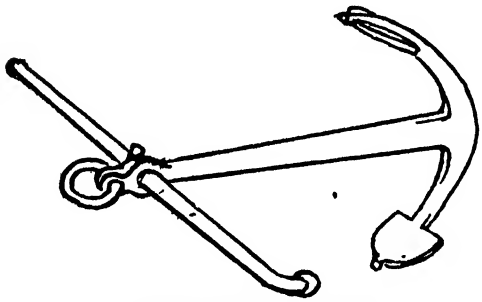
"Defender," Mr. May's 80h.p. boat at 21 knots.

ANCHORS.

Probably the most important part of nearly every vessel's equipment, next to the engine or sails, is the anchor. River boats naturally do not trouble much about anchors, but all boats should have one, and, in the case of a boat for sea use, the form, size, and consequent efficiency of the anchor should have the owner's most careful consideration. The number of different patterns of anchors is very considerable, but many of them are only suitable for large vessels, and others are of bad design.

Old Admiralty Pattern.

This is the regular stock pattern boat anchor which is sold by most of the yacht chandlers; in soft ground it holds very well, but it has one or two serious faults. The worst of these is that the shank—or that part extending from the

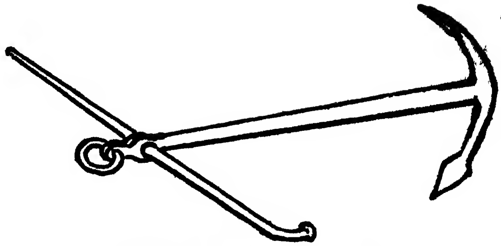


Old Admiralty pattern anchor.

arms to the ring—is too short in proportion to the arms or flukes; this makes the anchor liable to turn over, and bad at getting hold quickly. The palms are much too blunt and broad, making it difficult for the anchor to enter hard ground. It is also very heavy for its holding power.

Long-shank Fisherman's Anchor.

In this case all the principal faults of the old anchor have been eliminated; the shank is much longer and lighter, the arms shorter, and the palms sharp and shaped like a bay-leaf to enable them to enter the ground with the least possible resistance. No doubt it takes up rather more room than the Admiralty type, but weight for weight, it holds much better in all sorts of ground, except soft mud, and even then it is little if at all inferior. We should always



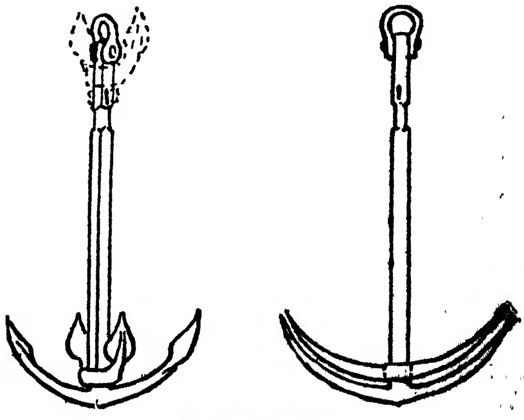
Long-shank fisherman's anchor.

advise the use of this anchor, if the trouble of stocking and unstocking is not objected to, as it is the best all-round anchor obtainable and very cheap.

Folding Anchors.

Where space is a great consideration, one of the many folding anchors may be used. Of these, the four-arm grapnel is at once the simplest and one of the best holders in all sorts of ground for its size and weight.

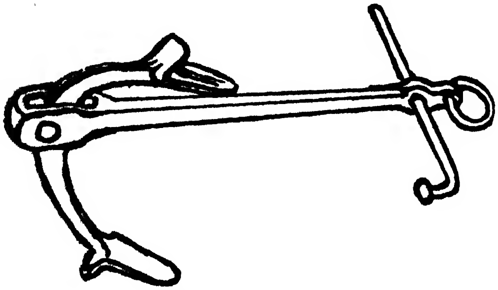
The upper pair of arms slide up and down on the square shank, and, when near the ring, may be revolved on the short rounded portion. They may also be fixed close to the ring to form a stock if desired, but, being short, are not very efficient in this position. It is chiefly suitable for boats of 25ft. and under, and it should not exceed 20lb. weight.



Four-arm grapnel.

Trotman's Anchor.

The Trotman anchor is a good holder and is not likely to foul the cable when in the ground, owing to the upper fluke being folded close to the shank, but it does not stow away so snugly

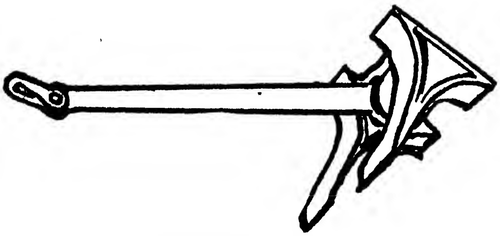


The Trotman Anchor.

as the grapnel, unless it be unstocked, and it has the significant nick-name of "thumb-pincher." It is a very good anchor for large yachts.

Wasteneys-Smith's Anchor.

This is a true stockless anchor and probably the best pattern, although there are one or two close imitations. It holds well, especially in the



The Wasteneys-Smith.

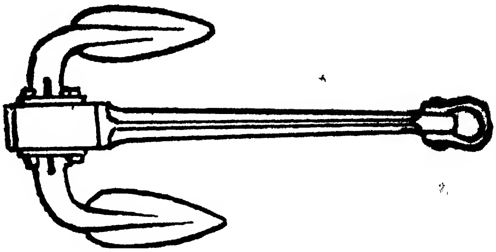
larger sizes, but is heavy for its holding power. Like all the stockless anchors, it is slow to get hold on hard ground in the small sizes, but it is a capital anchor for large vessels.

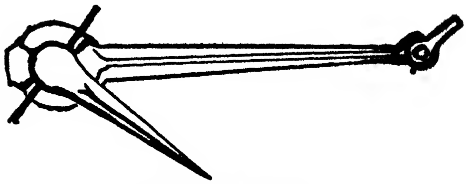
Simplex Anchor.

This is a similar type to the Smith, but much neater in appearance, and a little lighter in weight; it is also a good anchor in the larger sizes, but is occasionally inclined to roll over without getting hold when a small size is used on hard ground. For ordinary sand or clay it is an excellent anchor, and stows very snugly, and it can be carried in the hawse pipe like the Wasteneys-Smith anchor.

Hope-Chantrell Anchors.

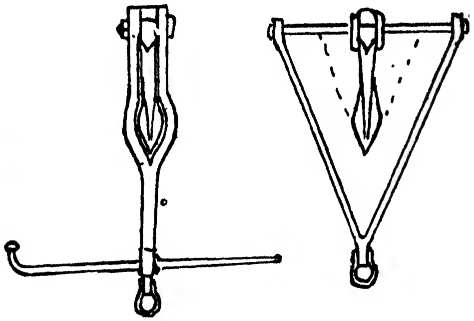
In both patterns of this anchor a single fluke travels through a double shank; it stows very well and holds well in all sorts of ground, but





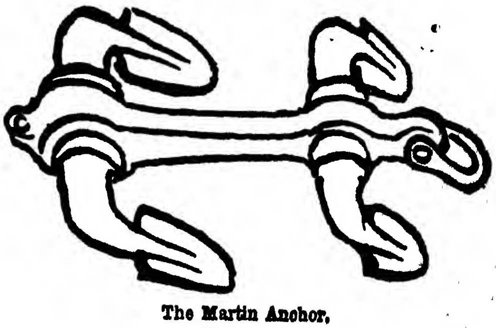
The Simplex Anchor.

is occasionally uncertain in getting hold. Another form of anchor has the pin on which the fluke revolves produced to form the stock, in place of the ordinary stock shown. This



Hope-Chantrell Anchors.

anchor was first patented by Mr. G. F. Chantrell, of Liverpool, in the 'seventies, and a similar anchor was again patented some ten years ago by Mr. W. Baden-Powell, K.C.



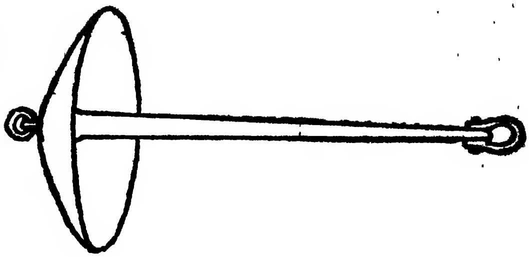
The Martin Anchor.

Martin's Anchor.

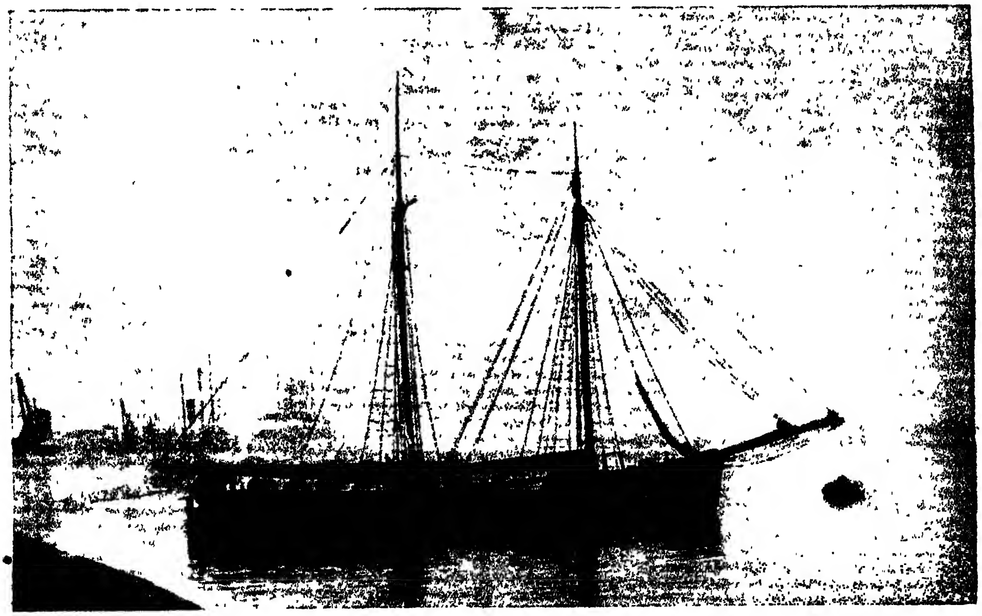
This is a great favourite on large steamers, and for this work it is one of the best anchors on the market, but it, like most of the folding anchors, is not so successful in the small sizes.

Mooring Anchors.

For moorings an old fisherman's anchor, with one fluke bent down, is the best for ordinary hard ground, while for mud the mushroom anchor is perhaps the best, although in this case a large piece of ballast, stone, or an old piece of machinery will hold well enough once it is buried.



Mushroom Anchor.



"Claggan," one of the first (possibly actually the first) coasting schooners in this country. Her principal dimensions are:—Length 78ft. 8in., beam 20ft. 7in., draught 8ft. 6in. A 28h.p. Kromhout engine is fitted, and the speed with 130 tons of cargo is 4½ knots.

SIGNALS AND SIGNALLING.

All who go "down to the sea in ships" should make themselves acquainted with at least the most commonly used of the flag signals. By this we do not mean to imply the ability to read messages which may be transmitted by a combination of flags—for that purpose an international signal code book is required, and should be carried in all vessels making considerable voyages. A knowledge of the principal national flags, the several flags used in the code signals, pilot flags of our own and other nations, and the several flags which have distinctive meanings, is always interesting, and may be of the utmost importance. We have, accordingly, included two plates of the chief national flags and of the international code flags, and on the latter plate are the burgees of the two marine motor clubs. Of the code flags when flown alone and without the code signal there are certain ones which have a special significance, among which may be mentioned the following:—

B flag means there is explosive aboard, or that explosives are being transferred.
C flag means yes or affirmative.
D flag means no or negative.
L flag means infectious disease aboard.
P flag means about to sail (" blue peter ").
Q flag means vessel is in quarantine.
S flag means vessel requires a pilot.

Apart from the ability to understand the meanings of flags, it is extremely useful at all times for boat owners and users to be able to receive and send messages between one craft and another or the shore when beyond hailing distance. There are two systems in common use for this purpose—Morse code and semaphore; both are given here, and we would strongly urge upon all

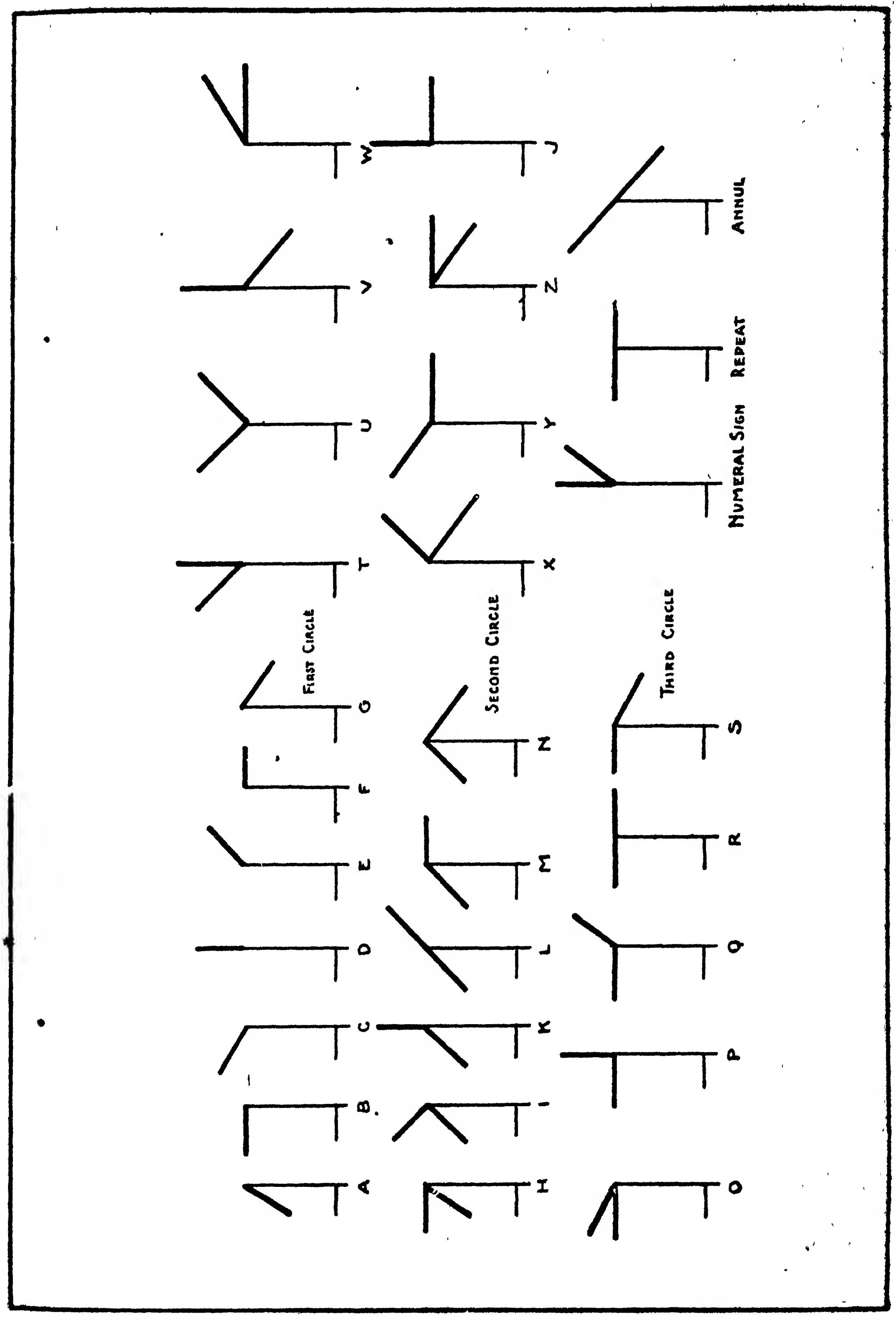
MORSE SIGNALLING CODE.

ALPHABET

A	\/	H	\\\\	O	///	V	\\\/
B	/\\\	I	\\	P	\//\	W	\//
C	/\/\	J	\///	Q	//\/	X	/\\/
D	/\\	K	/\/	R	\/\	Y	/\//
E	\	L	\/\\	S	\\\	Z	//\\
F	\\/\	M	//	T	/	REPEAT	\\//\\
G	//\	N	/\	U	\\/	NUMERAL SIGN	\\\\/\\

NUMERALS

1	\////	5	\\\\\	9	////\
2	\\///	6	/\\\\	0	/////
3	\\\//	7	//\\\	STOP	//////
4	\\\\/	8	///\\	CALLING UP	/////////



SEMAPHORE CODE.
"Circles" on the left. Miscellaneous letters and signs on the right.

sea-going marine motorists at least to learn one, if not both, and to practise on all available occasions.

All the coastguards, and the signalmen, and many officers in H.M. ships know both codes, and would be able to receive and reply to messages signalled to them.

Morse Signalling.

The Morse code consists of different arrangements of dots and dashes (or shorts and longs), which, on paper, may be represented in several ways, as F, . . — ., or — — —— —, or ııłı, or as shown in the alphabet appended. The code was originally designed by Mr. Morse for use with his electrical telegraph instruments, in which a lightly-balanced pointer ticks to one side or the other for dots or dashes.

In practical use, apart from electrical telegraph work, it may be employed in many ways, as an extreme instance of which we may mention that, in our juvenile days, when we were expected to be seen and not heard, we have, with a brother, criticised the assembled company at dinner by means of our toes, which met beneath the table. We have also used it in connection with wonderful (?) thought-reading demonstrations. But that is beside the present point; it merely serves to show the adaptability of the code.

The most usual method of signalling with the code over short distances in daylight is by means of a single flag on a handstaff. In the ready position this is held diagonally upwards over one shoulder, and a dot is signified by waving it halfway down on the other side, a dash being indicated by waving it right down, returning to the ready after each, and pausing at the end of a letter. The end of a word is shown by a longer pause, or by dropping the flag in front.

For long-distance signalling in sunlight the heliograph is used. This is an instrument for flashing a beam of reflected sunlight in the direction required, making short or long flashes. This method was largely used during the South African war, but is impracticable for the ordinary amateur, though we *have* used an ordinary hand mirror for the purpose with more or *less* satisfactory results.

For night work lamps are used, and the light shown for a short or long flash, being obscured between times; and this is the only practical method of signalling at night.

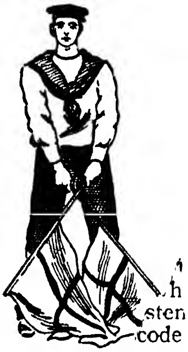
Many other ways of using this code, adapted to various circumstances, will occur to readers, such, for instance, as a horn, hooter, whistle, or bell in a fog.

The Morse code is the most generally useful for all-round purposes, but it is not so easily learnt or remembered, nor is it quite so quick in use for an amateur as the semaphore system of signalling.

Semaphore Signalling.

This code is easier to learn than the Morse, and is very much quicker to use, 10 words a minute being a rate of sending and receiving that anyone can attain after a reasonable amount of practice; it therefore entirely supplants the Morse code for ordinary daylight work with flags or semaphore arms, but on the other hand it is useless for heliograph and lamp signalling, so that, for all-round purposes, the Morse is the more useful.

In the diagrams of the letters it will be noticed that there is in every case a little horizontal arm at the bottom of the semaphore, which is used merely as an indication to show which side of



Semaphore signalling.

The "ready" position.

the semaphore resents the *sender's right hand.* If sig re sent with this arm on the other side the semaphore must be read as if a man were signalling with his back to the receiver.

The following are a few practical hints on the semaphore code :—

The ready position must be assumed at the end of each word.

The alphabet may conveniently be grouped in "circles" as shown, omitting the letter J, which is the opposite to P.

Letters from T onwards have to be remembered separately.

Numerals 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, are represented respectively by the letters A, B, C, D, E, F, G, H, I, K preceded by the numeral sign (opposite to T).

Semaphore signalling—the letter M.

To show a return from numerals to the alphabet the letter J must be signalled.

The annul signal is opposite to the letter L.

The repeat signal is the same as the letter R.

All letters of the first circle are made with the right hand only, the left being kept in the "ready" position in front of the body.

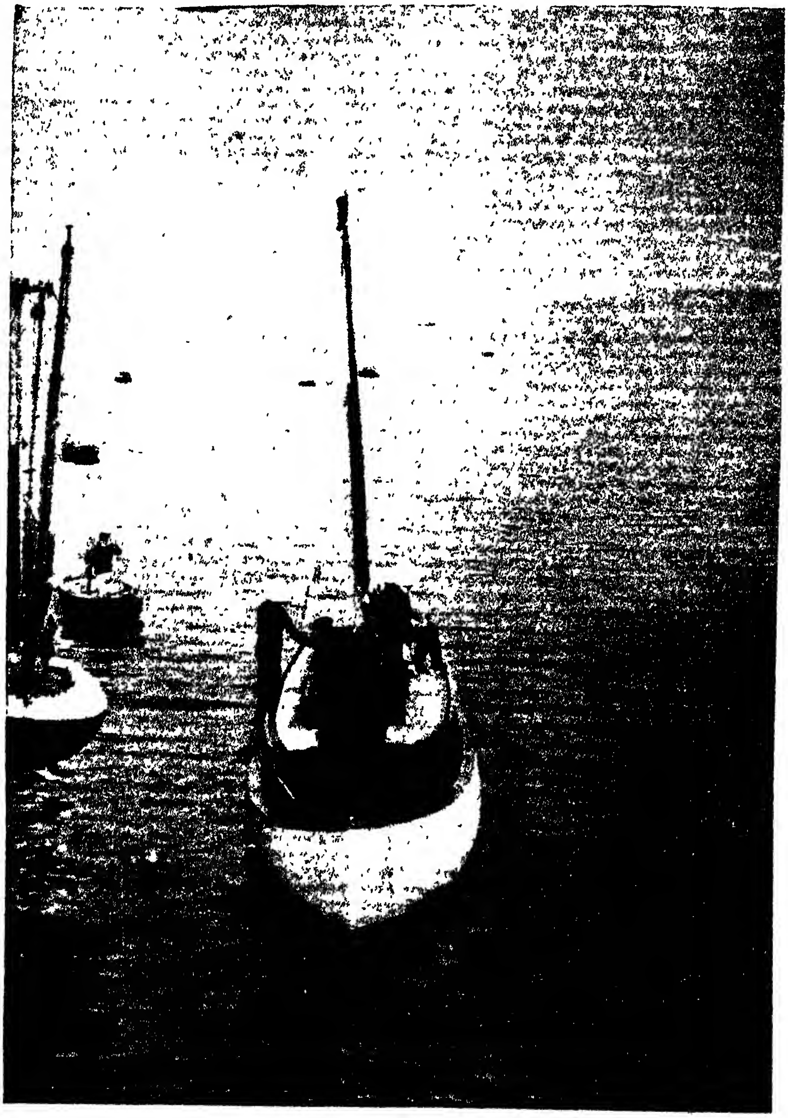
To call attention at the beginning of a conversation signal the letter J, but keep the right hand waving slightly, and continue to do so until answered.

When receiving a call answer with the letter J, to show that you are attending.

When a message is completed signal the letters VE.

When you have received and understood a message signal RD.

Practice makes perfect.



Off for a cruise: "Sphinx" in Southampton Water.

MISCELLANEA.

Information and Advice on Various Matters not Specifically Dealt with Elsewhere.

Flags and Flag Etiquette.

Their Use and Misuse.

The use, or misuse, of flags is one of the worst pitfalls for the novice who begins his boating career on fresh water, as there the law cannot touch him, no matter what offence he may commit against good taste and the rights of the Admiralty and the Royal and other Yacht Clubs.

Of course, such offences only bring down ridicule on the offender from every sailor of high or low degree; but the unfortunate man usually does not know that he is doing anything wrong, as he has no conception of the fact that every flag has its meaning, and anyone flying a flag to which he has no right is morally as great an offender as the man who puts a string of letters after his name implying that he is a member of some learned body with which he really has no connection.

Position in which to Fly them.

Apart from the question of what may or may not legitimately be flown there is a right and a wrong position in which to fly certain flags.

It is usual on launches to have a short vertical flag-staff forward on the stem head and a larger flag-staff at the stern either upright or with a rake aft. Only one flag can properly be flown from the after flag-staff, and that is the ensign of the country of which the owner is a subject. In the case of an owner who is not a member of a yacht club which is entitled to fly the white, blue, or red ensign with a club device he must fly no other flag on the ensign staff but a plain red ensign. The forward staff is used to fly a club burgee or the owner's private distinguishing flag, which should be a small rectangular flag about one-eighth the size of the ensign of any colour and device the owner may choose to adopt so long as it is not an imitation of some existing flag.

It is usual, however, to fly the burgee of some yacht or sailing club of which the owner is a member, on the forward staff in place of the private distinguishing flag, but unless the owner is a member of a club and has a right to fly the burgee no triangular or swallow-tail flag should be flown, as these shapes are only used for the burgees of the various clubs, with the exception of the flags of the international code of signals.

Flag Law.

Few landsmen know anything of the many strict and precise regulations which are in force regarding the flags which may or may not be used by different vessels and their owners. For instance, many yachtsmen even do not know that no one is allowed to fly even the red ensign if it has a device of any description on it, unless they have a personal warrant from the Admiralty giving them permission to fly a certain flag on one particular yacht only.

The White and Blue Ensigns.

The blue ensign is granted to vessels of the mercantile marine, commanded by an officer belonging to the Royal Naval Reserve, and having a certain number of R.N.R. officers or men in its complement; while the white ensign is reserved for His Majesty's ships, and privilege to use it otherwise is very rarely granted. The Royal Yacht Squadron is the only yacht club which enjoys the privilege, although it was formerly enjoyed by one or two other clubs.

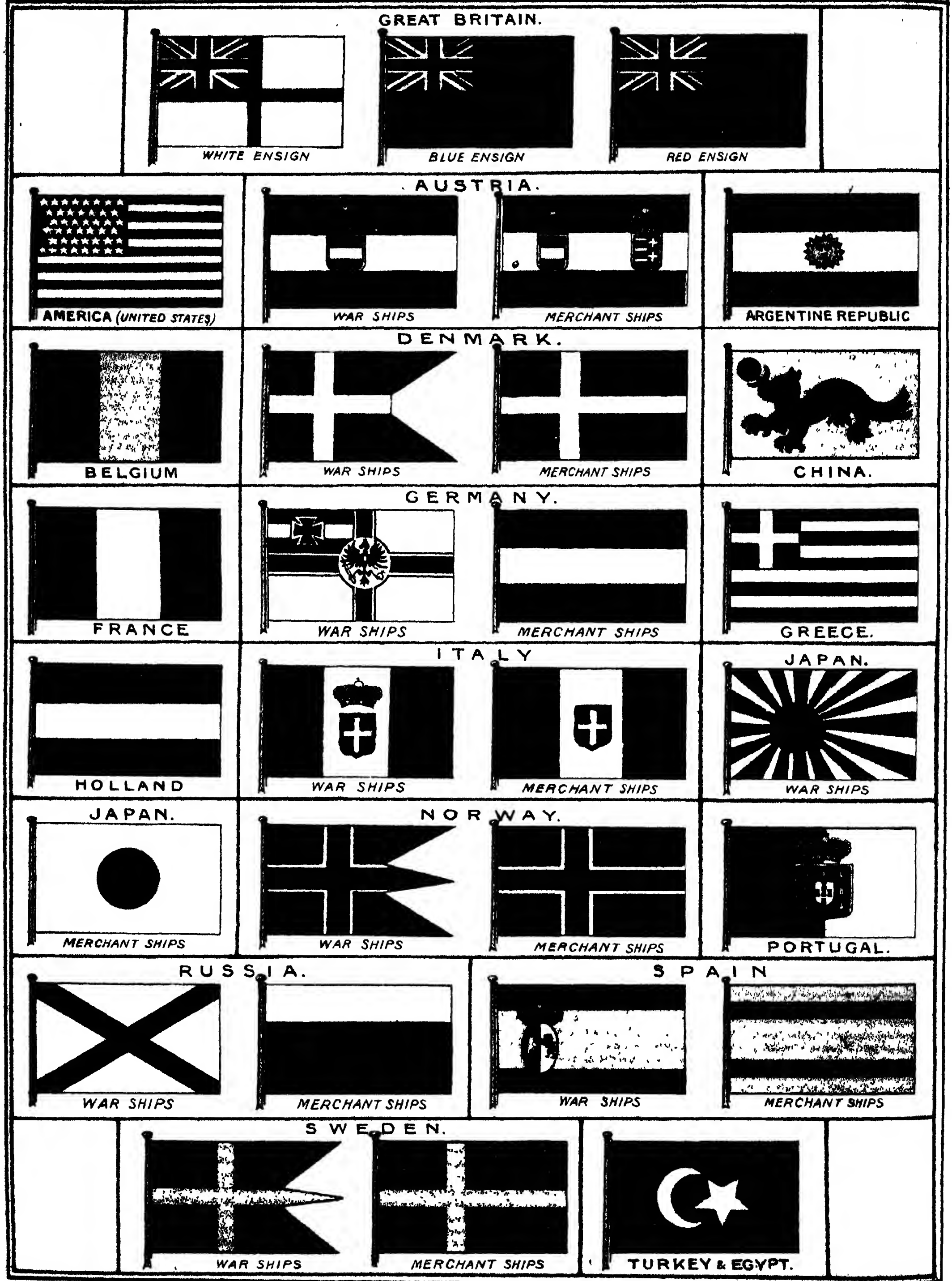
Penalties.

It will also be news to many, and probably somewhat of a shock, to learn that any person flying such a defaced flag, or the blue or white ensigns, with or without any device, even if he be a member of a club holding an Admiralty warrant to fly the flag, is liable to a penalty of not exceeding *five hundred pounds for the first offence*, unless he is the holder of a personal warrant from the Admiralty empowering him to fly the flag on that particular yacht. Any officer of the Navy, Consular Service, or Customs is, if on full pay, entitled to board a vessel flying such a flag with or without a warrant, and to confiscate the flag.

The Only Exception.

The only exceptions to these rules are boats belonging to yachts which have a warrant in proper form. In the case of all yachts holding an Admiralty warrant the boats are allowed to use the ensign on a staff over the stern when conveying the owner and his guests to and from the vessel, and in this case no special warrant is required for each boat. It must be understood, however, that boats carrying the ensign in this manner without a warrant must be bona-fide

NATIONAL FLAGS.



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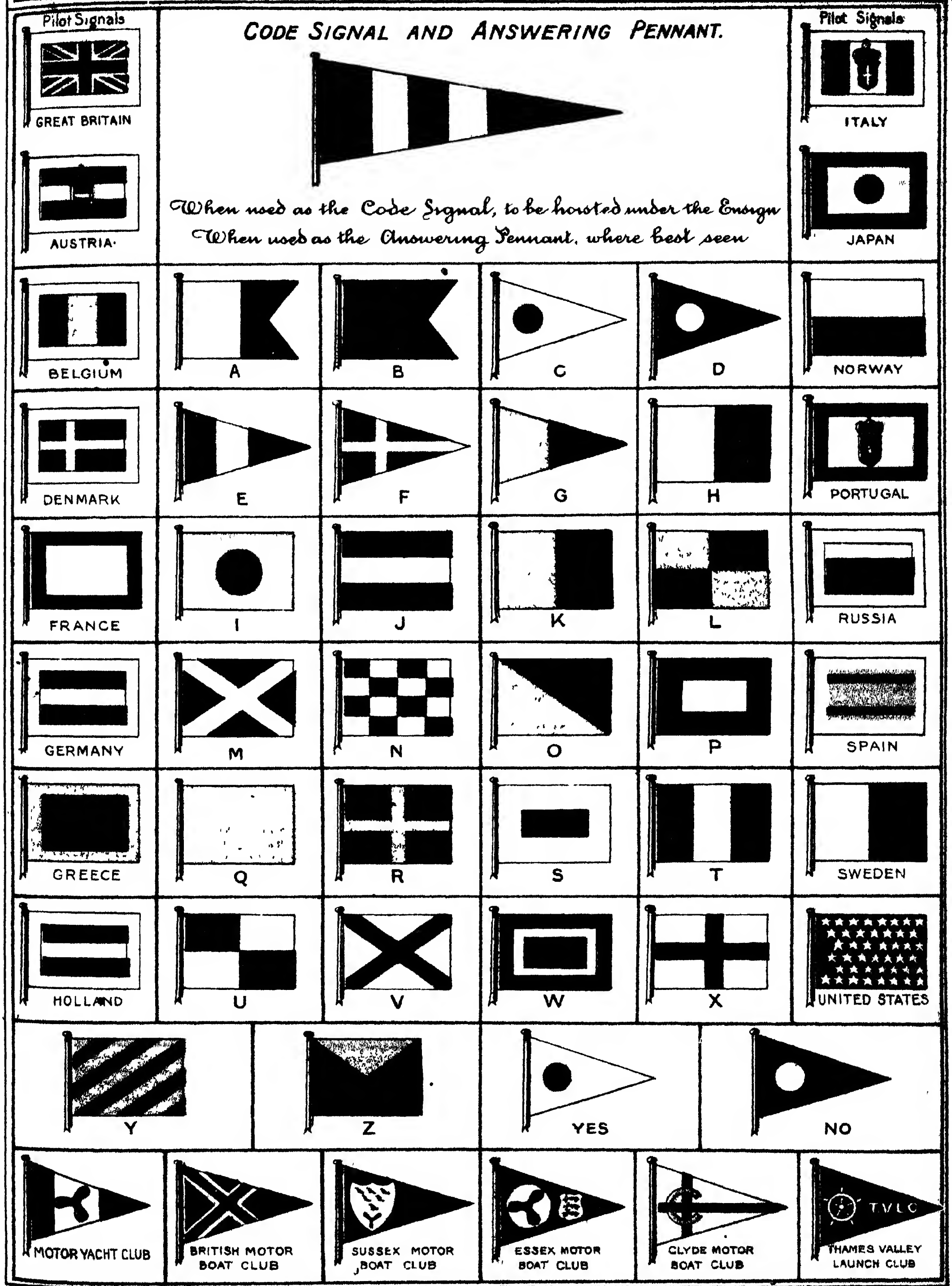
FLAGS OF THE INTERNATIONAL CODE OF SIGNALS, ETC.



The Motor Boat Manual

M^cCORQUODALE & C^o. LIMITED LONDON.

yacht's boats belonging to the yacht, and not merely boats such as launches or sailing boats owned by a man who holds a warrant for a yacht to which these boats do not belong. Each separate boat or launch not belonging to the yacht for which the warrant is issued, must have a separate warrant if the ensign is to be flown, and if one man owns half-a-dozen yachts and boats he must have a separate warrant for each one.

Where the Owner Joins Two Clubs.

When an owner belongs to two or more clubs, which are each entitled to fly the blue ensign, but with different devices in the flag, a separate warrant must be obtained for each club. Therefore, if, as often happens, an owner belongs to, say, six clubs, each of which is entitled to fly a different ensign, he must get six separate warrants for his boat if he wishes to be able to fly the ensign of each club when his yacht is on that station. If he also owns two or more boats, then he must get six warrants for each boat, in which case one would expect to find them nicely bound in a handy volume with an index for purposes of references. It certainly seems rather absurd to make a man carry a whole sheaf of warrants in this manner, and one would have thought that one warrant would have been enough if it were endorsed with the names and particulars of the yachts owned by the holder and also with the various clubs to which he belongs.

Warrants for Registered Vessels Only.

No Admiralty warrant will be issued to any yacht unless she is properly registered at the Customs House as a British ship, entirely owned by one or more British subjects. Many people have an idea that because a vessel's name appears in "Lloyd's Yacht Register" she is, therefore, a properly registered vessel. This is not the case, as "Lloyd's Yacht Register" is not the same as the "Custom House Register" at all, being merely a most useful list of particulars, etc., of all yachts of which they can be obtained by the compilers, while the "Custom House Register" is an official document, setting forth the ownership and all particulars as to the building and dimensions of the vessel, the name of the master, and the port to which she belongs. It is a most imposing piece of parchment, and is the principal paper required when visiting a foreign port, as it proves the identity of the vessel and her owner in somewhat the same manner as a passport.

Hired Yachts.

A warrant cannot be obtained for a hired yacht unless both owner and charterer are members of the same club; in this case a special written permission to fly the ensign can be obtained through the club secretary from the Admiralty. Although there is all this difficulty about flying the ensign on a hired yacht, there is no such restriction with regard to the club burgee, as this can be flown by any member of a club on any vessel he either owns or has chartered for the time being. This is still the case where the club holds a Royal warrant in addition to the Admiralty warrant, although the crown in the burgee is specified in the Royal warrant as well as the crown in the ensign, but in this case the warrant is granted to the club and all its members collectively, and not to individuals and separate boats, as in the case of the Admiralty warrant for the ensign. Therefore, although the burgee may not have a crown in it without a Royal warrant, still it may be used by all of the club members on any boats owned by them, whether registered or not.

How to Obtain a Warrant.

Before an Admiralty warrant can be obtained the yacht or boat must first be registered at the Customs House. To do this application must be made to the Customs House officials to have the boat measured, and the matter will then be referred to the Board of Trade, who will send a man down to measure the boat; the charges are merely for out-of-pocket expenses, in addition to a fee of one guinea for measuring. The owner must obtain a builder's certificate on the proper form, and this the builder must give when called upon. A declaration of ownership is also required, and a signed statement that the owner is a British subject. When all these papers and the certificate of measurement by the Customs House or the Board of Trade officer have been duly sent in, the Customs will send down an officer with the carving note, which is an order to cut a certain official number and tonnage on the main deck beam of the vessel (where there is no such beam available, it is cut on the coamings). As soon as the official number is carved and duly inspected, the register will be made out and handed over to the owner, who should fill in from it the various particulars required by the Admiralty and forward them to the secretary of his club requesting him to apply for a warrant.

Lights.

Every vessel, be she a motor dinghy or a yacht of considerable tonnage, is bound by law to carry proper lights when under way after sunset. The rules of the Thames Conservancy as to lights are slightly different to those required by the Merchant Shipping Act, which governs all vessels at sea outside the jurisdiction of the Thames Conservancy, whose authority extends down river to a line drawn from the Crow Stone, between Leigh and Southend on the Essex shore, to the Yantlet Beacon, on the Kent shore.

This difference consists solely in the regulations for the lights to be used on launches and other small power boats. Under the Merchant Shipping Act, a steam or motor launch may carry a single lamp with three lenses, showing white in the centre, red to port, and green to starboard, so arranged that the red light cannot be seen from any point on the starboard side, or the green light from any point on the port side.

Thames Regulations.

Such a tricolour lamp, however, is not permitted by the Thames Conservancy, who insist on three separate lamps similar to those carried by larger vessels, viz., a white masthead light, which shall be visible ahead and for two points abaft the beam on either side, to be carried at the masthead or, in the case of boats without masts, on a staff forward, above the level of the side-lights, or on the funnel if there is one. In addition to the masthead light, each vessel must carry a pair of side-lights, which shall be so arranged that each lamp shows a light directly ahead and extending to two points abaft the beam, the one on the left-hand or port side showing a red light, while that on the right or starboard side is to show a green light. Neither side-light must be visible from the opposite side of the boat, i.e., a vessel coming end-on would show a red and a green side-light, with a white masthead light over them in the form of a triangle, but directly she began to turn, say, to the right of the spectator, the red side-light would immediately be shut out, leaving the green and white lights only visible.

Steam or Motor-yacht Lights.

All sea-going or coasting yachts or other vessels of over 40 tons Customs House measurement must have a proper Customs House register, and all registered vessels, other than fishing boats, must carry the regulation Board of Trade lights, of not less than 8in. diameter in the globe or lens. Such lights must be suitably fixed, and screened to show over the regulation arcs as previously described, and, in addition, they must be visible for at least two miles on a clear night. The masthead light on such vessels must be carried at a height of 20ft. above the deck, and must be visible at least five miles. If the vessel is 100ft. in length or over, she should also carry a plain white light over her stern.

Power vessels of under 40 tons must carry, when under way at night, the following lights, viz.:—In the forepart of the vessel or on the funnel, at a height of not less than 9ft. above the gunwale, a bright white light, constructed and fixed as described previously, but which shall be visible at least two miles away. Also green and red side-lights, properly screened, at a distance of not less than 3ft. below the masthead or funnel light, and visible at least one mile distant. Small launches may carry the masthead or funnel light at a distance of less than 9ft. above the gunwale, but it must be above the coloured side-lights, except in the case of the combined tricolour lamp already described.

Responsibility.

It must be remembered that these lights are to be carried compulsorily, and, in the event of a collision occurring at night, any vessel failing to prove that she had the regulation lights burning brightly would not only be unable to claim for her own damages, but would have to pay for all damage to the other vessel.

Quite apart from the legal aspect of the case, owners should realise that slackness in the matter of carrying lights may easily result in a serious loss of life, for which they would be morally responsible.

Oil and Electric Lamps.

Most motor-boat owners like to use their boats occasionally after sunset, so we may consider the regulation masthead and side-lights as being among the most important fittings, especially on a river like the Thames, where there is a considerable amount of traffic and where the regulations respecting lights are rigidly enforced. Lamps can be obtained from any yacht fitter at various prices, from a sovereign for a set of three, if they are of plain japanned tin, up to three or four guineas for a set of copper lights fitted with the latest pattern burners and lenticular glasses. About fifty shillings a set is, however, a fair price for small copper lights to burn paraffin, and fitted with plain coloured glasses. These would be suitable for a river motor boat not exceeding thirty feet in length. For sea use it is better to have more powerful lights, and for this reason the lenticular and dioptric glasses are preferable on account of the greater brilliance of the light thereby obtained. With regard to burners, there are many patterns on the market, the earthenware Barton burner being probably the best for paraffin, as it not only gives a good light, but it is less likely to blow out than any other so far as my own experience goes, and at the same time it is particularly easy to keep clean and in working order. For those who can afford it, electric light is no doubt the best in every way, but unless the boat is large enough to carry a separate motor and dynamo for the purpose, a supply of accumulators must be carried for the lights, and these have to be frequently recharged, to say nothing of the initial outlay involved. Where electric lights are used, they should be fitted so as to ship on to plugs when in their places, and these may be supplied with switches or not as desired. In any case, the electric lamps should be easily removable, and a set of paraffin lamps and burners should always be carried ready for use in case the electric supply should fail. It is no excuse, when pulled up by the Conservancy for not showing the proper lights, to say that one has only electric light and the batteries are run down.

Signals to be Made by Ships Wanting Pilots.

In the Daytime.—The following signals, numbered 1 and 2, when used or displayed together or separately, shall be deemed to be signals for a pilot in the daytime, viz. :—

1.—To be hoisted at the fore, the Jack or other national colour usually worn by mechant ships, having round it a white border one-fifth of the breadth of the flag; or

2.—The International Code pilotage signal indicated by S.

At Night.—The following signals, numbered 1 and 2, when used or displayed together or separately, shall be deemed to be signals for a pilot at night, viz. :—

1.—The pyrotechnic light, commonly known as a blue light, every fifteen minutes; or

2.—A bright white light, flashed or shown at short or frequent intervals just above the bulwarks, for about a minute at a time.

A " flare " should not be used for this.

Use of Oil for Modifying the Effect of Breaking Seas.

The Board of Trade calls attention to the fact "that a very small quantity of oil, skilfully applied, may prevent much damage both to ships (especially the smaller classes) and to boats, by modifying the action of broken or troubled waters."

The principal facts as to the use of oil are as follows :—

1. On free waves—*i.e.*, waves in deep water—the effect is greatest.

2. In a surf, or waves breaking on a bar, where a mass of liquid is in actual motion in shallow water, the effect of the oil is uncertain, as nothing can prevent the larger waves from breaking under such circumstances; but even here it is of some service.

3. The heaviest and thickest oils are most effectual. Refined kerosene is of little use; crude petroleum is serviceable when nothing else is obtainable; but all animal and vegetable oils, such as waste oil from the engines, have great effect. In cold water, the oil, being thickened by the lower temperature, and not being able to spread freely, will have its effect much reduced. This will vary the description of oil used.

4. A small quantity of oil suffices if applied in such a manner as to spread to windward.

5. It is useful in a ship or boat, both when running or lying-to, or in wearing.

6. No experiences are related of its use when hoisting a boat up in a sea-way at sea, but it is highly probable that much time and injury to the boat would be saved by its application on such occasions.

7. The best method of application in a ship at sea appears to be: hanging over the side, in such a manner as to be in the water, small canvas bags, capable of holding from one to two gallons of oil, such bags being pricked with a sail needle to facilitate leakage of the oil.

The position of these bags should vary with the circumstances. Running before the wind they should be hung on either bow and allowed to tow in the water.

With the wind on the quarter the effect seems to be less than in any other position, as the oil goes astern while the waves come up on the quarter.

Lying-to, the weather bow and another position farther aft seem the best places from which to hang the bags, with a sufficient length of line to permit them to draw to windward while the ship drifts.

8. Crossing the bar with a flood tide, oil poured overboard and allowed to float in ahead of the boat, which would follow with a bag towing astern, would appear to be the best plan. As before remarked, under these circumstances, the effect cannot be so much trusted.

On a bar with the ebb tide it would seem to be useless to try oil for the purpose of entering, since it will be carried astern.

9. For a boat riding in bad weather from a sea anchor, it is recommended to fasten the bag to an endless line rove through a block on the sea anchor, by which means the oil is diffused well ahead of the boat, and the bag can be readily hauled on board for refilling if necessary.

Waterproof Clothing.

All users of motor boats are sure to require waterproof clothing of some description, so a few hints as to the best outfit and its proper choice and preservation may be of service to readers. The first point to be decided by the would-be purchaser of waterproofs for boat work is whether he will have true oilskins or rubber clothing, and this may to some extent be decided by the class of boating he proposes to go in for.

River Work.

On all sheltered waters where rain constitutes the most probable cause of a wetting, there is nothing more suitable than a good long mackintosh, provided it is impervious to the weather. Oilskins are, of course, equally efficient on the river or at sea, but the lighter and better ventilated mackintosh is not only far more comfortable to wear, but it is handier to carry about, and is useful for other purposes besides boating. For river boating, therefore, some form of mackintosh or gabardine in the shape of a long coat reaching to the ankles is preferable. For this work sea boots are not necessary, although they are very comfortable in cold weather.

Sea Work.

When one's cruising ground is the sea, the question of waterproofs must be looked at from quite a different standpoint. In this case, not

only will they have to withstand rain, but they must also be able to keep out heavy spray driven with considerable force, and in many cases what sailors call "solid" water, which may vary from half a bucketful to a green sea breaking over one's head. From the latter, even the best oilskins ever made will not give security from a partial wetting at the best, although it is surprising how much they will keep out if the collar fits properly and a good sou'-wester is worn. It is, therefore, strongly advisable to use regular seamen's oilskins, obtained from some respectable firm accustomed to supply seafaring men.

Choosing Oilskins.

The best oilskins are usually fairly stiff and rough. They should be of double thickness on the shoulders, and at all points where they are likely to get much rubbing. The collar should fit the neck fairly closely and come up as high as the ears, while the skirts of the coat should reach to about half-way between the waist and knees; the sleeves should be fairly long, with elastic wrist-bands inside; and the front of the coat should be double-breasted, the right-hand side buttoning over a wide flap and the left-hand side then covering the other, and buttoning across to the right over all. The trousers should always have a draw-string waist-band, and should come up as high as possible. One of the best patterns is the American one, in which the trousers have a chest flap, which buttons up to the neck with shoulder-straps from the back to keep it up. Do not get the expensive silk oilskins so frequently used by yachtsmen. Although they are much more comfortable and nicer to look at than the plainer sea-going oilies, they are more liable to become sticky than the others, and their cost is quite double.

The Care of Oilskins.

All waterproofs, no matter whether they are rubber or oilskins, should be dry before they are folded up, if they have to be stowed away in a bag or locker. It is best, however, to keep them hung up in a well-ventilated place. Oilskins especially suffer from want of ventilation, and should not only be kept hung up, but should also be spread out as much as possible by means of the loops provided for that purpose. If they are always kept in this manner they should last at least one or two seasons without becoming sticky, provided they are properly dressed to begin with.

Sea Boots.

These should be of black rubber, dull finish for choice and *unlined.* Lined sea boots are very warm and comfortable in the winter, but are liable to get permanently damp inside if they once get filled with salt water, as it is almost impossible to get the salt out of the felt linings. For this reason the unlined boots are the safest as well as the cheapest. Rubber boots should not be folded up if it can be avoided, for they soon crack across the instep, and then, of course, leak badly. A small leak in rubber boots may be repaired with a patch and solution from a cycle repair outfit, but at least a day must be allowed for the patch to dry.

Cleanliness.

To a yachtsman, of all people, cleanliness ranks next to godliness, and a dirty yacht is an abomination, therefore should motor yachtsmen and marine motorists generally cultivate the virtue.

For the marine motor it is usually claimed that it is much cleaner than a steam engine, and there is little doubt that this is absolutely correct in the abstract. In actual practice, however, especially on the higher-powered boats on the sea, it is, alas! only too common to find everything in a most untidy condition—with lubricating oil everywhere. That this can be avoided is evident from the beautifully-kept yachts' motor tenders to be seen alongside the Squadron steps and the steamboat pier at Cowes, where they are to be seen in dozens during Cowes week. The reason of all this is not far to seek. The yacht and her boats are all under the constant care of men whose whole lives have been spent in keeping vessels clean and up to the top notch of spit and polish, while, in nine cases out of ten, the motor boat is in charge of a mechanic who has not the faintest idea of cleanliness as it is understood by yachtsmen. The owner is often just as bad, if he has had no proper training on a smart yacht. He would doubtless prefer to have everything in apple-pie order, but it is too much trouble to do it himself if he has no man, and, if he has a mechanic, the latter is probably much too free and independent to condescend to clean brass work, or even to trouble to wipe his greasy hands before he touches clean brass or woodwork.

How to Keep a Boat Clean.

First of all, keep the boat tidy. Do not have a litter of empty petrol and lubricating oil cans all over the cockpit floor, with a profusion of dirty scraps of cotton waste, rusty spanners, and a general jumble of anchor, cable, oars, and boathook everywhere under foot. Instead, have lockers for everything, and make good use of them, putting each thing back in its place when finished with. Have a neat cover over the motor. See that proper drip trays are fitted under all the machinery, and also that oil guards are fixed over all parts whence oil is liable to be flung off. Keep the tools and oil cans as clean as possible, and, when one has to touch the motor, attempt to keep the hands as clean as possible. Plenty of clean waste, ready to hand but unobtrusive, is of the very

greatest advantage. If one is out in a bit of a sea, and everything gets well salted, no time should be lost in cleaning up all parts of the machinery. It is more satisfactory to clear up at once while things are wet, but if too late at night, have everything thoroughly cleaned first thing in the morning. Let your constant endeavour be to *prevent* dirt, not merely to clean it up, and so shall your boat become a credit to yourself and a pleasure to your friends.

Sundry Advice.

Don't try to go into or out of a lock except dead slow, and be sure you obey the orders of the lock-keeper.

Don't leave the fenders hanging over the side when you are under way, except when going in or out of a lock or alongside a landing-stage.

Don't have a lot of flowers on deck; they may look very well on a houseboat, but they are quite unsuitable and most unseamanlike on any other boat.

Don't keep your side-lights and mast-head light in their places during the daytime or at any time when they are not lighted; they should only be put up when they are required, from sunset to sunrise when the launch is under way.

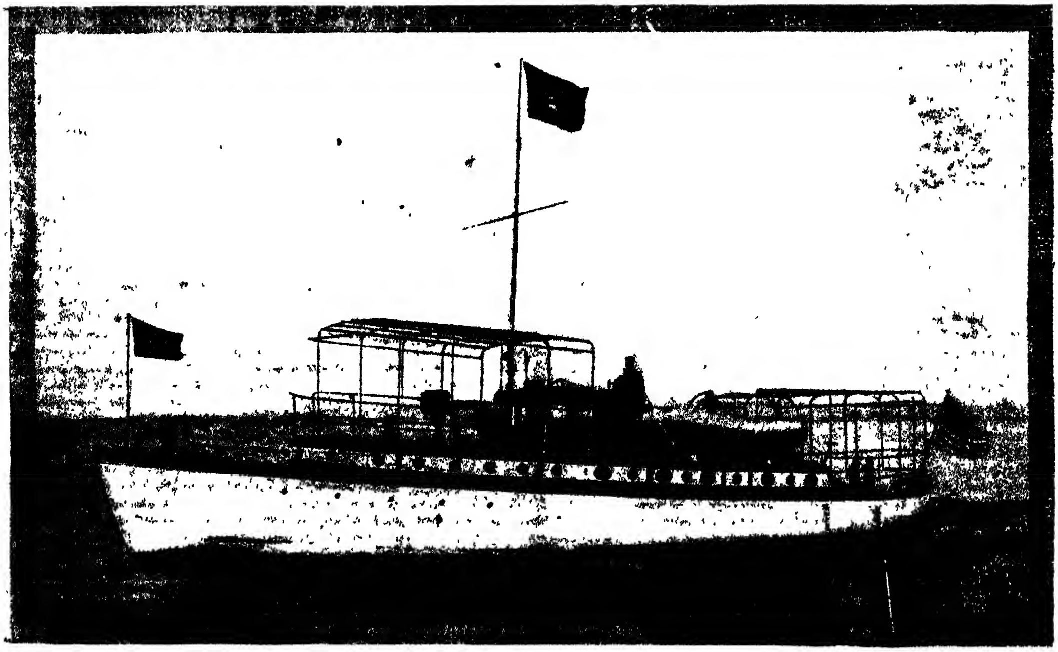
Don't fly flags from sunset to 8 a.m.

Don't wear fancy yachting caps and bogus badges—they only give you away to all yachting men.

Don't use a club burgee or ensign on any but your own private boat even if you are a member of the club.

Don't fly a big flag with the firm's name on the ensign staff if you are connected with the marine motor trade, and have a launch which is used as an advertisement.

Don't deface any of the ensigns by putting the firm's name in the fly. You should fly a plain red ensign aft and a smaller rectangular flag forward with the name of the firm.



An American motor yacht.

BOARD OF TRADE REGULATIONS FOR PREVENTING COLLISIONS AT SEA.

These regulations are included here because every owner of a sea-going vessel should be thoroughly conversant with them. It will be noticed that the Board of Trade definition of a "steam vessel" includes any vessel propelled by machinery, so that all types of motor craft fall within these regulations. In the event of any occurrence, the owner will be presumed to have a knowledge of them, and a plea of ignorance will not be accepted in defence of a contravention of any of their articles.

SCHEDULE I.

Preliminary.

These rules shall be followed by all vessels upon the high seas and in *all waters connected therewith, navigable by sea-going vessels.*

In the following rules every steam vessel which is under sail and not under steam is to be considered a sailing vessel, and every vessel under steam, whether also under sail or not, is to be considered a steam vessel.

The word "steam vessel" shall include *any vessel propelled by machinery.*

A vessel is "under way" within the meaning of these rules when she is not at anchor, or made fast to the shore or aground.

Rules Concerning Lights, etc.

The word "visible" in these rules, when applied to lights, shall mean visible on a dark night with a clear atmosphere.

Article 1.—The rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such time no other lights which may be mistaken for the prescribed lights shall be exhibited.

Article 2.—A steam vessel when under way shall carry—

(a) On or in front of the foremast, or, if a vessel without a foremast, then in the fore part of the vessel, at a height above the hull of not less than 20ft., and if the breath of the vessel exceeds 20ft., then at a height above the hull not less than such breadth, so, however, that the light need not be carried at a greater height above the hull than 40ft., a bright white light, so constructed as to show an unbroken light over an arc of the horizon of 20 points of the compass, so fixed as to throw the light 10 points on each side of the vessel—viz., from right ahead to two points abaft the beam on either side, and of such a character as to be visible at a distance of at least five miles.

(b) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of 10 points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side, and to be visible at least two miles.

(c) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of 10 points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side, and of such a character as to be visible at a distance of at least two miles.

(d) The said green and red side lights shall be fitted with inboard screens projecting at least three feet forward from the light, so as to prevent these lights from being seen across the bow.

(e) A steam vessel when under way may carry an additional white light similar in construction to the light mentioned in sub-division (a). These two lights shall be so placed in line with the keel that one shall be at least 15ft. higher than the other, and in such a position with reference to each other that the lower light shall be forward of the upper one. The vertical distance between these lights shall be less than the horizontal distance.

Article 3.—A steam vessel when towing another vessel shall, in addition to her side lights, carry two bright white lights in a vertical line one over the other, not less than six feet apart, and when towing more than one vessel shall carry an additional bright white light six feet above or below such lights, if the length of the tow, measuring from the stern of the towing vessel to the stern of the last vessel towed, exceeds 600ft. Each of these lights shall be of the same construction and character, and shall be carried in the same position as the white light mentioned in Article 2 (a), except the additional light which may be carried at a height of not less than 14ft. above the hull.

Such steam vessel may carry a small white light abaft the funnel or aftermast for the vessel towed to steer by, but such light shall not be visible forward of the beam.

Article 4 (a).—A vessel which from any accident is not under command shall carry at the same height as the white light mentioned in Article 2 (a), where they can best be seen, and if a steam vessel, in lieu of that light, two red lights, in a vertical line one over the other, not less than six feet apart, and of such a character

as to be visible all round the horizon at a distance of at least two miles; and shall by day carry in a vertical line one over the other, not less than six feet apart, where they can best be seen, two black balls or shapes, each two feet in diameter.

(b) A vessel employed in laying or in picking up a telegraph cable shall carry in the same position as the white light mentioned in Article 2 (a), and, if a steam vessel, in lieu of that light, three lights in a vertical line one over the other, not less than six feet apart. The highest and lowest of these lights shall be red, and the middle light shall be white, and they shall be of such a character as to be visible all round the horizon at a distance of at least two miles. By day she shall carry in a vertical line one over the other, not less than six feet apart, where they can best be seen, three shapes not less than two feet in diameter, of which the highest and lowest shall be globular in shape and red in colour, and the middle one diamond in shape and white.

(c) The vessels referred to in this article, when not making way through the water, shall not carry the side lights, but when making way shall carry them.

(d) The lights and shapes required to be shown by this article are to be taken by other vessels as signals that the vessel showing them is not under command, and cannot therefore get out of the way.

These signals are not signals of vessels in distress and requiring assistance. Such signals are contained in Article 31.

Article 5.—A sailing-vessel under way, and any vessel being towed, shall carry the same lights as are prescribed by Article 2 for a steam-vessel under way, with the exception of the white lights mentioned therein, which they shall never carry.

Article 6.—Whenever, as in the case of small vessels under way during bad weather, the green and red side lights cannot be fixed, these lights shall be kept at hand lighted and ready for use; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side, nor, if practicable, more than two points abaft the beam on their respective sides.

To make the use of these portable lights more certain and easy, the lanterns containing them shall each be painted outside with the colour of the light they respectively contain, and shall be provided with proper screens.

Small Vessels.

Article 7.—Steam vessels of less than 40, and vessels under oars or sail of less than 20 tons gross tonnage respectively, and rowing boats, when under way, shall not be obliged to carry the lights mentioned in Article 2 (a) (b) and (c), but if they do not carry them they shall be provided with the following lights:—

1. Steam-vessels of less than 40 tons shall carry:

(a) In the fore part of the vessel, or on or in front of the funnel, where it can best be seen, and at a height above the gunwale of not less than nine feet, a bright white light constructed and fixed as prescribed in Article 2 (a), and of such a character as to be visible at a distance of at least two miles.

(b) Green and red side lights constructed and fixed as prescribed in Article 2 (b) and (c) and of such a character as to be visible at a distance of at least one mile, or a combined lantern showing a green light and a red light from right ahead to two points abaft the beam on their respective sides. Such lantern shall be carried not less than three feet below the white light.

2. Small steamboats, such as are carried by sea-going vessels, may carry the white light at a less height than nine feet above the gunwale, but it shall be carried above the combined lantern, mentioned in sub-division 1 (b).

3. Vessels under oars or sails, of less than 20 tons, shall have ready at hand a lantern with a green glass on one side and a red glass on the other, which, on the approach of or to other vessels, shall be exhibited in sufficient time to prevent collision, so that the green light shall not be seen on the port side nor the red light on the starboard side.

4. Rowing-boats, whether under oars or sail, shall have ready at hand a lantern showing a white light, which shall be temporarily exhibited in sufficient time to prevent collision.

The vessels referred to in this article shall not be obliged to carry the lights prescribed by Article 4 (a) and Article 11, last paragraph.

Article 8.—Pilot-vessels, when engaged on their station on pilotage duty, shall not show the lights required for other vessels, but shall carry a white light at the masthead, visible all round the horizon, and shall also exhibit a flare-up light or flare-up lights at short intervals, which shall never exceed fifteen minutes.

On the near approach of or to other vessels they shall have their side lights lighted, ready for use, and shall flash or show them at short intervals, to indicate the direction in which they are heading, but the green light shall not be shown on the port side, nor the red light on the starboard side.

A pilot-vessel, of such a class as to be obliged to go alongside of a vessel to put a pilot on board, may show the white light instead of carrying it at the masthead, and may, instead of the coloured lights above mentioned, have at hand ready for use a lantern with a green glass on the one side and a red glass on the other, to be used as prescribed above.

Pilot-vessels, when not engaged on their station on pilotage duty, shall carry lights similar to those of other vessels of their tonnage.

Article 9.—This article will deal with regulations affecting fishing boats, and will be the subject of another order, which will be submitted to His Majesty for approval at a later date.

Article 10.—A vessel which is being overtaken by another shall show from her stern to such last mentioned vessel a white light or a flare-up light.

The white light required to be shown by this article may be fixed and carried in a lantern, but in such case the lantern shall be so constructed, fitted and screened, that it shall throw an unbroken light over an arc of the horizon of 12 points of the compass, viz., for 6 points from right aft on each side of the vessel, so as to be visible at a distance of at least one mile. Such light shall be carried as nearly as practicable on the same level as the side lights.

Article 11.—A vessel under 150ft. in length, when at anchor, shall carry forward, where it can best be seen, but at a height not exceeding 20ft. above the hull, a white light in a lantern so constructed as to show a clear, uniform, and unbroken light visible all round the horizon of a distance of at least one mile.

A vessel of 150ft. or upwards in length, when at anchor, shall carry in the forward part of the vessel, at a height of not less than 20 and not exceeding 40ft. above the hull, one such light, and at or near the stern of the vessel, and at such a height that it shall not be less than 15ft. lower than the forward light, another such light.

The length of a vessel shall be deemed to be the length appearing in her certificate of registry.

A vessel aground in or near a fairway shall carry the above light or lights, and the two red lights prescribed by Article 4 (a).

Article 12.—Every vessel may, if necessary, in order to attract attention, in addition to the lights which she is by these rules required to carry, show a flare-up light or use any detonating signal that cannot be mistaken for a distress signal.

Article 13.—Nothing in these rules shall interfere with the operation of any special rules made by the Government of any nation with respect to additional station and signal lights for two or more ships of war or for vessels sailing under convoy, or with the exhibition of recognition signals adopted by shipowners, which have been authorised by their respective Governments and duly registered and published.

Article 14.—A steam vessel proceeding under sail only, but having her funnel up, shall carry in daytime, forward, where it can best be seen, one black ball or shape two feet in diameter.

Sound Signals for Fog, etc.

Article 15.—All signals prescribed by this article for vessels under way shall be given:

(1) By "steam vessels" on the whistle or siren.

(2) By "sailing vessels and vessels towed" on the fog-horn.

The words "prolonged blast" used in this article shall mean a blast of from four to six seconds' duration.

A steam vessel shall be provided with an efficient whistle or siren, sounded by steam or some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog-horn, to be sounded by mechanical means, and also with an efficient bell. In all cases where the rules require a bell to be used, a drum may be substituted on board Turkish vessels, or a gong where such articles are used on board small sea-going vessels. A sailing vessel of 20 tons gross tonnage or upwards shall be provided with a similar fog-horn and bell.

[*It should be noted that a "hooter" cannot be regarded as equivalent to a whistle in sea-going craft.*—Ed.]

In fog, mist, falling snow, or heavy rain storms, whether by day or night, the signals described in this article shall be used as follows:—

(a) A steam vessel having way upon her shall sound, at intervals of not more than two minutes, a prolonged blast.

(b) A steam vessel under way, but stopped and having no way upon her, shall sound, at intervals of not more than two minutes, two prolonged blasts, with an interval of about one second between them.

(c) A sailing vessel under way shall sound, at intervals of not more than one minute, when on the starboard tack one blast, when on the port tack two blasts in succession, and when with the wind abaft the beam three blasts in succession.

(d) A vessel, when at anchor, shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds.

(e) A vessel, when towing, a vessel employed in laying or in picking up a telegraph cable, and a vessel under way, which is unable to get out of the way of an approaching vessel through being not under command, or unable to manœuvre as required by these rules, shall, instead of the signals prescribed in sub-divisions (a) and (c) of this article, at intervals of not more than two minutes, sound three blasts in succession—viz., one prolonged blast followed by two short blasts. A vessel towed may give this signal, and she shall not give any other.

Sailing vessels and boats of less than 20 tons gross tonnage shall not be obliged to give the above-mentioned signals, but if they do not they shall make some other efficient sound signal at intervals of not more than one minute.

Speed of Ships to be Moderate in Fog, etc.

Article 16.—Every vessel shall in a fog, mist, falling snow, or heavy rain storms, go at a moderate speed, having careful regard to the existing circumstances and conditions.

A steam vessel hearing, apparently forward of her beam, the fog-signal of a vessel the position of which is not ascertained, shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

Steering and Sailing Rules.

Risk of Collision.

Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

Article 17.—When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other, as follows, viz:—

(a) A vessel which is running free shall keep out of the way of a vessel which is close-hauled.

(b) A vessel which is close-hauled on the port tack shall keep out of the way of a vessel which is close-hauled on the starboard tack.

(c) When both are running free, with the wind on different sides, the vessel which has the wind on the port side shall keep out of the way of the other.

(d) When both are running free, with the wind on the same side, the vessel which is to windward shall keep out of the way of the vessel which is to leeward.

(e) A vessel which has the wind aft shall keep out of the way of the other vessel.

Article 18.—When two steam vessels are meeting end on, or nearly end on, so as to involve risk of collision, each shall alter her course to starboard so that each may pass on the port side of the other.

This article only applies to cases where vessels are meeting end on, or nearly end on, in such a manner as to involve risk of collision, and does not apply to two vessels which must, if both keep on their respective courses, pass clear of each other.

The only cases to which it does apply are, when each of the two vessels is end on, or nearly end on, to the other; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own; and by night, to cases in which each vessel is in such a position as to see both the side lights of the other.

It does not apply, by day, to cases in which a vessel sees another ahead crossing her own course; or by night, to cases where the red light of one vessel is opposed to the red light of the other, or where the green light of one vessel is opposed to the green light of the other, or where a red light without a green light, or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

Article 19.—When two steam vessels are crossing, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other.

Article 20.—When a steam vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the steam vessel shall keep out of the way of the sailing vessel.

Article 21.—Where by any of these rules one of two vessels is to keep out of the way, the other shall keep her course and speed.

Note.—When, in consequence of thick weather or other causes, such vessel finds herself so close that collision cannot be avoided by the action of the giving-way vessel alone, she also shall take such action as will best aid to avert collision. (See Articles 27 and 29.)

Article 22.—Every vessel which is directed by these rules to keep out of the way of another vessel, shall, if the circumstances of the case admit, avoid crossing ahead of the other.

Article 23.—Every steam vessel which is directed by these rules to keep out of the way of another vessel shall, on approaching her, if necessary, slacken speed or stop or reverse.

Article 24.—Notwithstanding anything contained in these rules, every vessel overtaking any other shall keep out of the way of the overtaken vessel.

Every vessel coming up with another vessel from any direction more than two points abaft her beam, i.e., in such position, with reference to the vessel which she is overtaking, that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

As by day the overtaking vessel cannot always know with certainty whether she is forward of or abaft this direction from the other vessel, she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

Article 25.—In narrow channels every steam vessel shall, when it is safe and practicable, keep to that side of the fairway or mid channel which lies on the starboard side of such vessel.

Article 26.—Sailing vessels under way shall keep out of the way of sailing vessels or boats fishing with nets, or lines, or trawls.

This rule shall not give to any vessel or boat engaged in fishing the right of obstructing a fairway used by other vessels other than fishing vessels or boats.

Article 27.—In obeying and construing these rules, due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate danger.

Sound Signals for Vessels in Sight of One Another.

Article 28.—The words "short blast" used in this article shall mean a blast of about one second's duration.

When vessels are in sight of one another, a steam vessel under way, in taking any course authorised or required by these rules, shall indicate that course by the following signals on her whistle or siren, viz.:—

One short blast to mean, "I am directing my course to starboard."

Two short blasts to mean, "I am directing my course to port."

Three short blasts to mean, "My engines are going full speed astern."

No Vessel Under any Circumstances to Neglect Proper Precautions.

Article 29.—Nothing in these rules shall exonerate any vessel, or the owner, or master, or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper look out, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

Reservation of Rules for Harbours and Inland Navigation.

Article 30.—Nothing in these rules shall interfere with the operation of a special rule, duly made by local authority, relative to the navigation of any harbour, river, or inland waters.

[*The Thames Conservators and other river and harbour authorities adopt special rules for their several districts.*—ED.]

SCHEDULE II.

Distress Signals.

Article 31.—When a vessel is in distress and requires assistance from other vessels or from the shore, the following shall be the signals to be used or displayed by her, either together or separately, viz.:—

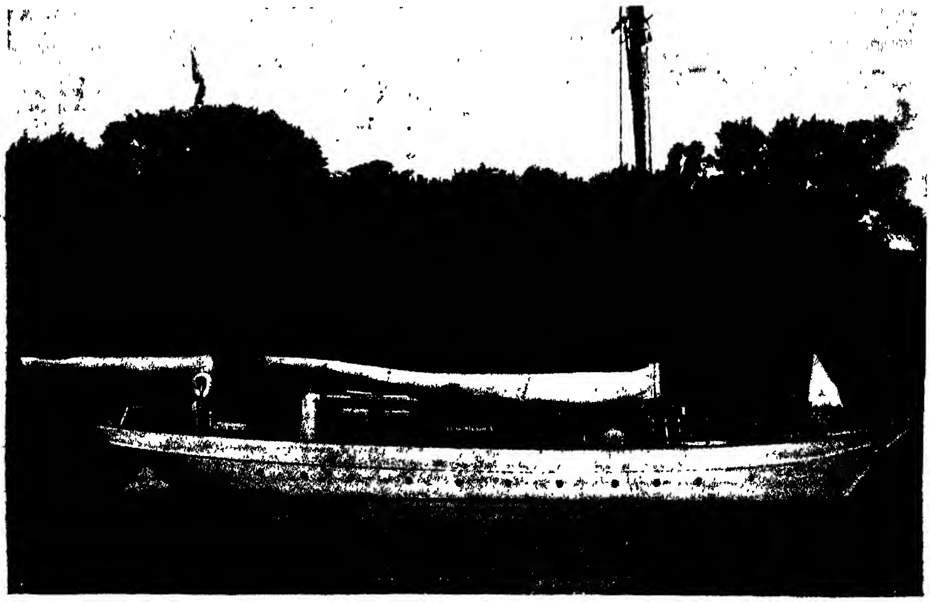
In the daytime—

1. A gun or other explosive signal fired at intervals of about a minute.
2. The International Code signal of distress indicated by flags N.C.
3. The distant signal, consisting of a square flag, having either above or below it a ball or anything resembling a ball.
4. A continuous sounding with any fog-signal apparatus.

At night—

1. A gun or other explosive signal fired at intervals of about a minute.
2. Flames on the vessel (as from a burning tar-barrel, oil-barrel, etc.).
3. Rockets or shells, throwing stars of any colour or description, fired one at a time, at short intervals.
4. A continuous sounding with any fog-signal apparatus.

[*Distress signals should never be made without adequate cause.*—ED.]



"Quo Vadis," a Dutch yacht.

BYE-LAWS FOR THE REGULATION OF PETROL MOTOR LAUNCHES ON THE THAMES.

1.—These Bye-laws may be cited as "The Thames Motor Launch Bye-Laws 1906" and shall come into operation the day after the same are confirmed by the Board of Trade

2.—These Bye-laws shall be applicable to the Thames as defined by the Thames Conservancy Act 1894. [It is possible that the Port of London Bill before Parliament as we go to press may affect the regulations, though we do not anticipate that they will be materially altered.—ED.]

Definitions.

3.—In these Bye-laws the words and expressions hereinafter mentioned shall have the meanings hereby assigned to them respectively unless there be something in the subject or context repugnant to such construction viz. :—

The expression "petrol motor launch" means any vessel in which the motive power is supplied by petroleum to which the Petroleum Acts 1871-1879 apply* whether such petroleum is used in an internal combustion engine or for the generation of steam or otherwise but the said expression shall not include a petrol motor launch having no petroleum on board when being towed.

The word "master" when used in relation to any petrol motor launch means any person whether the owner master or other person lawfully or wrongfully having or taking the command charge or management of the petrol motor launch for the time being.

The expression "Officer of the Conservators" means any lockkeeper or other officer of the Conservators or any person employed by them and authorised by writing under their Common Seal to carry out the provisions of these Bye-laws.

Installation Requirements.

4.—No petrol motor launch shall be navigated into or through any lock on the Thames unless it is constructed in accordance with the following requirements :—

Carburetters.

(a) Carburetters (the design or construction whereof may in any circumstances permit of an overflow) so fitted as in the event of an overflow to drain into a gauze-covered receptacle capable of being emptied from time to time as may be necessary and of a form to be approved by the Conservators.

Fuel Tanks and Stowage.

(b) Fuel tanks constructed of copper or an alloy of copper riveted or of steel efficiently galvanised after making up and their freedom from leakage or liability to leakage ascertained by testing.

(c) A closed locker provided for the stowage of petrol cans whether containing petrol or not such closed locker not to be placed in close proximity to the exhaust pipe.

(d) Fuel tanks installed in such a position that ready access can be had to all connections.

Fuel Pipes.

(e) All fuel pipes of seamless drawn copper or other tubing approved by the Conservators.

(f) Fuel pipes fitted with ground cone union joints or other approved form of joint and not with flange or socket joints. The main fuel pipe provided with suitable means for giving it the necessary elasticity. If bends or coils are fitted one should be placed close to the fuel tank and another close to the carburetter.

(g) Fuel pipes carried where they are least liable to become damaged and in all cases so fitted that ready access can be had to them and all connections throughout their entire length.

Cocks on Pipes.

(h) One cock fitted to the fuel feed pipe where it leaves the tank and another where it joins the carburetter. Provided that in respect of petrol motor launches registered prior to the date when these Bye-laws come into operation and having only one cock in the fuel feed pipe the Inspector of the Conservators shall exercise his discretion as to the necessity of a second cock to such pipe.

* *Flash point, 73° F., which does not include ordinary paraffin.*

Exhaust Pipes.

(*i*) The exhaust pipe water cooled unless taken into a funnel. Where the exhaust pipe is taken into a funnel provision made to prevent liability of ignition of inflammable vapour in any part of the boat.

Silencer.

(*j*) The silencer effective as regards suppression of noise of exhaust to the satisfaction of the Conservators and constructed of sufficient strength to prevent it being injured by the occurrence of an explosion therein.

Engine Tray.

(*k*) A spirit-tight tray or receptacle the sides of which are carried up as high as the propeller shaft will permit of fitted beneath the engine so as to prevent leakage of spirit and lubricating oil escaping into any other part of the boat.

Ignition Arrangements.

(*l*) The ignition circuit throughout carefully insulated. High tension leads from coil to sparking-plugs carried through a water-tight tube or so installed as to prevent leakage of current or risk of breakage or damage by water.

(*m*) Electric leads properly supported.

(*n*) If a " spark gap " be employed it must be so enclosed as not to be capable of igniting inflammable vapour.

(*o*) Some form of sparking plug employed in which external sparking is as far as possible guarded against.

(*p*) If trembler coils are employed the same must be placed in a position where an accumulation of inflammable vapour is not likely to occur.

(*q*) No form of hot tube ignition employed.

Facilities for Inspection.

5.—The master of every petrol motor launch whilst waiting to enter or when in any lock on the Thames shall give to any Officer of the Conservators reasonable facilities to inspect such petrol motor launch with a view to ascertaining whether the aforesaid requirements are complied with.

Action to be Taken.

6.—Whilst waiting to enter or when in any lock on the Thames the master of any petrol motor launch and the person or persons on board the same shall comply with the following regulations :—

Fuel to be Shut Off.

(*a*) Having entered a lock the cock on the fuel feed pipe shall immediately be closed and shall not be re-opened until the lock gates are opened for the egress of the vessel or vessels then in the lock.

Engine to be Stopped.

(*b*) In any lock the engine shall be stopped before the lock gates are closed and shall not be re-started until the gates are opened for the egress of the vessel or vessels then in the lock. Provided that sub-sections (*a*) and (*b*) of this Bye-law shall not apply to a petrol motor launch when no other vessel is passing through the lock at the same time as the petrol motor launch or when the only other vessel or vessels passing through the lock at the same time as the petrol motor launch is or are a vessel or vessels of the same type.

Manipulation of Fuel.

(*c*) No fuel tank or petrol can shall be opened or manipulated on any petrol motor launch.

(*d*) Any petrol carried in excess of that contained in the fuel tanks shall be carried only in two-gallon cans of a pattern approved by the Railway Clearing House for conveyance of petrol by the Railway Companies. Such cans whether containing petrol or not shall be stowed in a closed locker which must not be used for any other purpose while any petrol can is therein.

Matches.

(*e*) No person shall strike a match whilst on any petrol motor launch. Provided that this regulation shall apply only when such petrol motor launch is in a lock.

Prevention of Fire.

(*f*) With a view to prevention of fire a proportionate quantity of sand equal to one-half a cubic foot for every complete 12 feet in length of the hull of the petrol motor launch together with a shovel or scoop shall be carried in some readily accessible place. Provided that in the event of the Conservators approving in writing under the hand of their Secretary a form of chemical fire extinguisher such approved chemical fire extinguisher may be carried in place of sand aforesaid.

Penalty.

7.—Any person acting in contravention of any of these Bye-laws shall for every such act be liable to a penalty not exceeding £10 and in the case of a continuing offence to a further daily penalty not exceeding the like amount which said penalties shall be recoverable enforced and applied according to the provisions of the Thames Conservancy Act 1894.

Inspection and Certificate.

NOTE.—The Conservators will be prepared to inspect any petrol motor launch registered under the Thames Conservancy Act 1894 and grant to the owner of such launch, if on such inspection it be found to satisfy the requirements as to construction, a certificate of compliance with reference to that part of these Bye-laws relating to construction.

Such certificate of compliance will not however exempt the master of such petrol motor launch from liability to have his vessel further inspected from time to time in order that it may be ascertained whether the construction has been maintained in accordance with the aforesaid requirements.

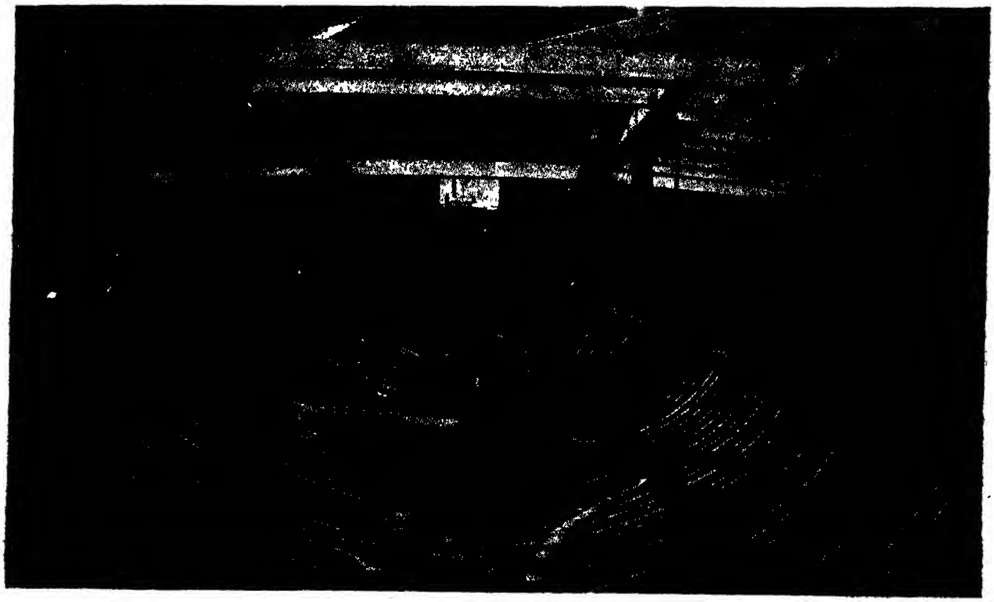
Applications for inspection of petrol motor launches should be addressed to the Secretary, Thames Conservancy, Victoria Embankment, London, E.C.

These Bye-laws were confirmed by the Board of Trade on August 11th, 1906, and will be enforced from January 1st, 1907.

Registration.

Every vessel propelled by mechanical power and used on the river above Kew Bridge is, by the Thames Conservancy Act 1894, required to be registered and the charge for a certificate expiring at the 31st December following the date of issue is £1.

Forms of application for certificates can be obtained at the Thames Conservancy Office, Victoria Embankment, London, E.C.



M.Y. "Trident" under construction, looking aft.

SUGGESTED RULES TO BE OBSERVED IN CARRYING OUT MARINE MOTOR INSTALLATIONS.

These notes have been drawn up with a view to assisting prospective owners of motor craft in the selection of a motor and the arrangement and fitting of the whole installation in a vessel. The notes must be accepted merely as a guide to really good practice, and installations must not of necessity be condemned because they do not in all respects come up to the ideal here laid down.

Installing the Motor.

Engine Beds.—In boats fitted with single or double-cylinder four-stroke engines, or single-cylinder two-stroke engines, the engine bearers should be arranged to provide against considerable athwartships strains, and engines giving over 10h.p. should be provided with fore and afters carried as far aft as the floor of the boat will allow. For boats of over 20h.p., and with less than ¾in. planking, and with three or four-cylinder engines, the fore and afters should form the main support, and should extend as far fore and aft as the lines of the boat will allow. They should be joggled over timbers and provided with waterways at each side of timber. Further, hard wood knees or gussets should be fitted at every other timber for the length of the engine and reverse gear, and at every third timber fore and aft of this.

Fitting Bearers.—Bearers should be fitted into the boat during construction if possible, joggled over clench planking, and accurately fitted to carvel boats and substantially secured.

Holding-down Bolts.—Holding-down bolts should consist of studs with plate nuts mortised into bearer, or so arranged that the stud can be withdrawn if it should become injured. Also the stud should be arranged to be entered after the engine has been placed in position. Holding-down bolts should not be less than ½in. in diameter in any case. In vessels with a skin or skins of 1¼ or more, the thwartship or fore and aft bearers can further be secured by passing four metal bolts of the same diameter as those used in the engine right through bearer, timber, and skin. Such bolts to have mushroom heads, and substantial washers outside, and to be screwed and nutted on the inside. Such bolts should not pass through the engine.

Horn Plates.—Horn plates of engine should be on centre line of shaft, and high enough to allow the fore and after to be placed over the engine floors, which, in turn, should clear the crank-chamber by an inch or two inches.

Thrust Bearers.—Thrust and reverse gear should have their bearers in line with the engine bearers and be fitted to the same fore and afters.

Drip Trays.—A copper or brass drip tray or trays should be fitted to all classes of installation in such a manner that all lubricating oil or paraffin will be collected and drained to a sump, from whence it can easily be removed, by hand in small installation, and by a suitable permanent pump in cases of over 20m.p. This applies to all points when oil, grease, or fuel (paraffin) may be thrown or dropped. All flywheels or such-like parts should be provided with a guard that will catch all oil and deliver same to tray.

Drip Tank.—In the case of petrol engines carburetters should be so constructed that a tank can be placed close up to same, which tank should be provided with a fine gauze top and a drain cock. Further, the engine tray should be so arranged that should the petrol connection to the engine be accidentally severed, the petrol will flow into the tray. However, this does not apply to the drip or leak from the carburetter, which should not be allowed to take place into the engine tray direct, but the tray must be arranged to catch leak or overflow from drip tank.

Fuel Storage.

Small Installation.—In installations where not more than 10 gallons of fuel are carried a brass or copper tank can be used, placed under the fore deck or other suitable position. The tank should not be less than 20b.w.g., and should be seamed, annealed, and soldered. All connections, including the filling pipes, should be carried on one end plate of not less than 16b w.g., and such connections should be back-nutted and soldered in position. A floor should be placed under the tank below the level of and away from all cocks or connections, in order that the same may not be damaged. Efficient ventilation should in all cases be provided for such locker or compartment.

Large Installation.—In installations carrying above 10 gallons of fuel, and in decked or covered craft not using pressure feed, the tanks may be of irregular shape, providing they will stand a pressure of 10lb. per square inch without permanent distortion; but such tanks should be carried in a separate compartment, arranged in such a manner that it is impossible for the fuel to drain into the bilge in case of a leak either from tank, connection, or filling plug.

Filling Pipes.—All filling pipes or stoppers should be taken to the outside.

Top Connections.—All tanks which have any part of them below the water-line, or less than 1ft. above the adjacent floorboard, should have the connections at the top. In this case, as in all others, the connection plate should either be of 16b.w.g., or be

strengthened for not less than 6in. from this connection with 14b.w.g. plate, and all joints should be made with ample flanges, back-nutted, and the whole soldered.

Fuel Pump.—If petrol be used, and if it be pumped up from the store tank to the running tank, a semi-rotary pump may be used placed in an accessible position in full view.

Strainers.—All filling holes in tank should be fitted with a fine gauze tube that is closed at the bottom.

Filters.—All outlets should be provided with an efficient filter in the shape of a gauze tube extending at least 2in. into the interior of the tank, or, otherwise a filter which may be easily cleaned should be fitted in the supply pipe.

Pressure Feed.—Pressure feed tanks for petrol should be cylindrical and fitted with semi-spherical ends, and may be either of brass, copper, or steel properly galvanised. All such tanks should be tested up to 30lb. to the square inch, and all connections made at the top.

Store Tanks.—Large store tanks on decked craft can be placed in the wings, or where convenient, and the compartment should be bulkheaded and floored in such a manner that should a leak occur the fuel will not reach the bilges. In the case of petrol a double tank should be provided, the inner and outer tank separated by wood strips. The outer tank should be ventilated and provided with a sounding well in order that any accumulation of water can be pumped out and a leak of petrol brought to notice. Such tanks should be riveted and galvanised, or, if of copper or yellow metal, they should be riveted and soldered, and should, as regards strength, be in accordance with Lloyd's regulations for water tanks. The petrol or oil connection to engine should be provided with a concertina joint or turn-in pipe.

Fuel Supply System.

The first consideration of all pipe connections, pipes, cocks, etc., must be security from leakage.

The whole system should be devised and installed in such a manner that the ordinary usage will not cause damage and leakage.

The rule with regard to connections to tanks should be strictly followed, and the fittings employed should be as follows:—

Directly fitted into the tank should be a male end union cock, with back nut. The cock should be of the long barrel plug variety, such as is used for high-pressure steam. To this should be attached the concertina joint. A female end, with inserted nipple and back nut, should not be allowed. The union should be of the semi-spherical or cone ground variety, and be fitted with substantial nuts to fit standard spanner. Screwed connections or brass gaspipe and fittings cannot be allowed, either on the engine itself or elsewhere.

Dimensions.—The fuel connections should be at least of the following dimensions: Pipe ¼in. bore by ⅜in. outside, ⅝in. over socket, 1in. over thread, 12 threads per inch, and the nuts to be for ⅞in. spanner. These fittings to be made of gunmetal, navy bronze, or other suitable substance.

Wheel Valves.—Good quality wheel or globe valves may be used as stop valves provided they meet with the above specifications, or are provided with a flange plate, which plate should be bolted and soldered to the tank.

Fuel Pipes.—All fuel [illegible] should not be less than ¼in. by ⅜in., and sh[illegible] be brazed into union sockets, pipes be accurately bent so as to lead quite true from union without forcing, and after being adjusted to position all pipes should be taken down and annealed.

Filters.—Any filters, water separators, or other filling should be provided with similar connections to above. A similar cock should be fitted to the carburetter or its equivalent by connecting the cock to the pipe and permanently securing the other part of the cock union fitting to the carburetter.

Testing.—If deemed necessary, all pipe lines and fittings (exclusive of tank, carburetter, etc.) shall be subjected to a pressure of 150lb. All wheel valves, pump glands, etc., should be packed with worsted and yellow soap.

Protection of Pipes.—All fuel pipes should be carried in such positions that they will be safe from mechanical injury, and yet as free as possible from corrosive action of the bilge. Also the feed pipe should be arranged so that air pockets are not likely to be formed. In large decked craft ¼in. by ⅜in. seamless copper tube served with spun yarn may be used, drawn through lead pipes under the above circumstances. In decked craft all down pipes should consist of ¼in. by ⅜in. copper, served with spun yarn, and passed through iron gas barrel or copper tubes of suitable sizes. The ends of such pipes should be caulked with spun yarn and payed with marine glue, and the envelope pipe terminal should be received by a chock or socket.

Tanks on Deck.—In the case of fuel tanks on deck a cock should be fitted to the tank, and at least one complete turn placed in pipe between deck and cock. The pipe should pass through a boss at least 2in. high, secured to deck over a rubber washer or ring, which will make a flexible watertight joint. The top of such boss should be sharply countersunk and payed with marine glue.

Quality of Pipe.—All copper pipes should be solid drawn copper and thoroughly annealed before and after being shaped, except such pipes as pass through guard tubes which cannot be annealed after bending.

Pipe Leads.—If it is necessary to carry a fuel pipe from one part of the vessel to another, and if it has to be placed in such a position that it is not open to inspection, or if it contains a number of bends, lead pipes ¼in. bore by ⅝in. outside diameter may be used. Standard connection should be brazed into a length of copper pipe, and the lead pipe swelled to receive same at least 2in., and blowpipe solder must be used and fluxed right in and on the top of joint.

Fixing of Pipes.—All pipes should be secured by wood or fibre cleats at such intervals as will prevent abrasion by vibration. No pipe should lie adjacent to any hard substance without being secured to same.

Circulating Water System.

All water service pipes should consist of solid drawn copper of 16b.w.g. minimum, with bronzed metal flanges, the thickness of which should not be less than one-third the diameter of pipe, and secured by not less than four bolts or studs, yellow metal only being used. Joints to be made with rubber insertion.

Ground Unions.—Where the construction of the engine will not allow of the above, ground unions

made of gunmetal and brazed on to pipe may be substituted. It is necessary, however, that all connections should be of the same standard throughout. Screwed connections or brass gaspipe and fittings cannot be allowed.

Seacock.—Seacock and strainer should be of such a pattern that the sea strainer can be cleared while the boat is under way. This is to be accomplished by mounting a gate valve directly over the strainer, and immediately over this a tank divided by a gauze strainer and provided with a manhole. The gauze should be vertical, so that the hand can be used to clear away any obstruction, or same be pushed through the strainer. In jobs of less than 20h.p., in place of above a two-way cock may be mounted over the sea strainer in such a manner that if turned in one direction a rod can be passed down to free strainer. A cap should be provided to screw on to the two-way cock.

Circulating Pump.—All circulating pumps should be firmly attached to engine casting. Pumps fitted to engine bearers or floors, and driven by chains or belts, ought not to be installed save in such exceptional cases as may be justified by circumstances. The outlet to above must deliver above the water-line. In sea-going craft of over 20h.p., or craft to be licensed for passengers, a duplicate system of cooling should be provided, and for this purpose a suitable hand pump will suffice.

Draining.—The water circulation system should be so arranged that the pump and pipes as well as the water jackets can be drained.

Bilge Pump.—A bilge pump worked from the engine that can be brought into operation when required is desirable. Such pump should be of not less than the capacity of the circulating pump, but the bilge water must not be passed through the jacket. The size of water service pipe should be not less than that which has been provided for by the makers of the engines. The outlet or overflow should be carried out above the water-line.

Fastenings.—All fittings fastened to the ship side must be held by metal bolts.

Class of Pipes.—All pipes should be solid drawn copper of not less than 16b.w.g., and flanges to be of copper or brazing metal, or unions of gunmetal, navy bronze, or other suitable alloy. All bolts studs and nuts (except studs on engine) should be of yellow metal. Pipes should be annealed before and after bending.

Exhaust.

All exhaust pipes should be water cooled from the point of attachment to the engines to their outlet.

Two-stroke.—In small two-stroke installations this may be accomplished by turning part of the circulating water into the interior of the exhaust pipe.

Four-stroke.—In four-stroke jobs of more than one cylinder a cast iron or made-up copper receiver must be arranged to attach to the engine direct.

Receiver.—The following remarks apply only to those cases where a silencer is fitted, and this may usually be dispensed with, as explained in the chapter on "Silencers."

Exhaust pipes should be of solid drawn copper not less than 16b.w.g., and the jacket formed of tube not less than 18b.w.g. The terminals of such pipes should consist of a flange or spigot, the thickness of spigot being not less than ⅜in. up to 3in internal bore, and ½in. for over this up to 5in. bore, and ⅝in. beyond this.

The exhaust pipe should be entered in the flange spigot, and the spigot should, in turn, be entered into the jacket pipe.

Connection from jacket to jacket should consist of "U" tubes, connected by ground unions made on saddle pieces.

Flanges, which should be of yellow metal, saddle pieces, etc., must be brazed on to the pipe.

Circulating Water.—The whole of the circulating water should be passed through the jacket or jackets, and the overflow should be higher than the inlet to the system, and the area of connections should be equal to the engine water service.

Internal By-pass.—At the terminal of this jacket part of the water should be turned into the exhaust pipe through a by-pass regulating valve and a check valve. The by-pass pipe should lead, when in the exhaust, towards the exhaust outlet.

Silencer.—A galvanised silencing drum to stand a pressure of 50lb per square inch can be arranged at the terminal of the exhaust, such drum to have a capacity of at least twenty times the capacity of one cylinder. The entry of the chamber must be close to the top of same, and the outlet at the bottom. In most cases, however, a silencer may be entirely dispensed with. A straight run of pipe can be taken aft (it is very important to avoid U bends), and all circulating water should be turned into this pipe, 18in. or 2ft. from the engine. With about 15ft. or more of pipe an ample degree of silence may be obtained in this way. The outlet should be above the water line

Expansion Bend.—It is preferable that this bend be unjacketed and constructed in such a manner that the same will act as an expansion joint.

Drain.—A draincock that can easily be manipulated should be placed at the lowest point of the exhaust system.

Exhaust Outlet.—The exhaust may terminate below the water in large boats of comparatively low power, the terminal consisting of a hood under water facing aft, with a flange accurately bedded to the skin of the boat.

A spigot formed with the outside flange should pass through the skin and loose flange and then bend forward, and this spigot should terminate in a flange screwed on, which will be bolted to the flange on the silencer. Such joints, however, must be accessible.

All flange fittings, bolts, etc., should be made of gunmetal or an approved bronze.

A blank flange with rubber insertion should be provided and secured in an accessible place in sight, and near to the silencer, so that the same may be fitted to the terminal in case of total breakdown or rupture of silencer.

Baffle Plates.—The silencer, if fitted, should be, as far as possible, free from baffle plates or tubes having small apertures.

The exhaust pipe, silencer, etc., must be firmly held and secured to the vessel in such a manner that abrasion will not be occasioned by vibration.

Commercial.

In commercial and other craft with cargo hold aft of engine room the exhaust should be taken out at the side just below the deck.

In auxiliary sailing vessels a branch should be carried out on both sides.

Commercial craft having an exhaust pipe over 3in. in diameter may substitute iron steam pipe and steam fittings for copper.

Exposed Flame.—No form of exposed flame or hot tube ignition should be allowed for petrol engines.

Blow Lamp.—Blow lamps for vaporiser and ignition tubes (except for starting up) should be avoided whenever possible, and in such cases as they are used provision should be made for ventilation and protection from fire.

Fire Extinguishers.

All motor-propelled craft should carry fire extinguishers of such a pattern as will adequately deal with a fire caused by the ignition of half-gallon of petrol poured into the engine tray.

Ignition System.

Low Tension.—In sea-going boats low-tension ignition should be employed whenever possible.

Batteries.—Where low-tension ignition of the battery supply system is installed, all accumulators or batteries must be carried as high up as possible and stowed in a box lined with some acid proof composition. At least two sets of batteries must be carried, and in the case of vessels for use in tidal water some primary form of generation must be carried of a permanent type, such as a dynamo generator or primary batteries.

Duplicates.—It is, however, preferable, in all sea-going installations, that a dynamo generator with permanent field magneto shall be arranged to be coupled in parallel at will with the requisite number of accumulators and the ignition system.

Coils.—All impedence or self-induction coils should be enclosed and saturated with paraffin wax.

Switches.—All switches should be of the water-tight marine type.

Leads.—All electrical leads should have not less than seven conductors of at least 24b.w.g., insulated with vulcanised rubber to a minimum of 1,000 megohms per mile, and be further insulated with braid and compounded and enclosed in lead or fibre armour.

Terminals.—All terminals of wire should be finished with brass or copper clips and taped off.

Reverse Gear.

This should be carried on metal bearers or connections built on to or connected with engine, in order that the alignment may always remain correct.

Thrust.—Thrust bearings should also be carried in this way.

Neutral.—The reversing gear must be capable of being left in the neutral position without a rise in temperature of any one part of more than 20 degrees F. after an hour's running.

Clutches.—Clutches should be metal-to-metal, and the whole should be enclosed and run in oil.

Accessibility.—The reverse gear should be capable of being removed without shifting the engine or propeller shaft, and should be reasonably accessible for inspection.

Deck Control.—For commercial vessels it is essential that the control of the propeller from ahead through neutral to astern, etc., should be carried out by one lever independent of the condition of rotation of the engine. That is to say, for instance, by a hand on deck who has not access to or sight of the engine.

Shafting.

Propeller Shaft.—May be of steel or metal, and tail-shaft should be of metal, with solid flanges in both cases, flanges to be provided with spigots and turned parallel or taper bolts.

In special cases, such as flat-floored boats, steel flanges may be fitted to the shaft, in which case they should be fitted with feather and cotter, and be shrunk on to the shaft.

The minimum diameter of mild steel propeller shafts should be equal to 2.5 per cent. of the total piston area.

Stern Tube.—For less than a 3-inch shaft the stern tube and fittings should be of metal, with substantial flange containing gland on inside with at least two bolts passing through same, and a flange with spigot outside through which the stern tube will pass. The spigot of the loose flange would fit into the stern post, and would be hauled up by a substantial nut, which would in turn be locked by a set screw screwing into the flange and engaging in a recess provided for it in the nut.

A guard should be provided attached to the plate and designed to envelop the propeller boss, in order that cordage, etc., shall not jamb between the stern post and propeller. This guard must be in halves.

The stern tube should be lined with white metal and be bored to receive shaft, and a recess made at or near the centre with a pipe leading from same, such pipe being not less than ¾in. diameter, and brought up as far above the water-line as possible. This would terminate in a covered box or filler, into which oil would be poured.

In iron vessels the loose flange outside can be dispensed with and the tube made to fit hole in stern post.

When the shaft exceeds 3in. it can be of steel with a metal sleeve shrunk on, in which case the sleeve, as regards diameter, must be over and above the required diameter of shaft.

In shafts over 3in. the stern tube may be of steel and lined with either white metal or lignum; in the latter case, the oiling device can be dispensed with, except that a grease cup must be provided at the gland.

Shaft Bearings.—These may be of white metal or bronze.

Stern Bearings for Flat-bottom Boats.—In this class of vessel, where the shaft passes out through the floor at an angle, a solid sleeve with diagonal plates inside and out must be used, the inside plate being cast in one with the tube, and the outside and inside being bolted together, with the skin of the bolt, keelson, or hog and keel between.

The sleeve must be lined with white metal or lignum, and provided with a stuffing-box inside, and the gland must be provided with a grease lubricator.

Whistle.

All vessels of 10 tons and over should be provided with a suitable whistle or siren. "Hooters" should not be used in any vessel.

Controls.

All decked vessels, when the control of the propeller is carried out from the deck, should be provided with duplicate control in the engine room, and, further, provided with telegraph, bells, or voice tube.

Spare Gear.

In all sea-going craft or vessels intended for carrying passengers on tidal waters, the following spare gear should be carried as a minimum:—

One piston complete with connecting rod and all accessories.

Two sets of piston rings.

Set of crankshaft brasses.

A set of valves complete.

One set of valve-actuating gear.

If camshaft wheels are outside crank-chamber and are exposed, a complete set of such wheels, as well as a camshaft, should be carried, together with keys or other fittings.

Set of moving parts for circulating pump.

If stand-by ignition is not fitted, a complete set of ignition gear must be carried, including all motions, magneto generator, etc. In any case, two sets of wearing parts such as electrodes must be carried.

Enough electrical wire to rewire the installation should be provided.

A duplicate of every spring on engine and gear.

A duplicate of every connection.

Wearing or breakable parts of the clutch and reversing gear.

A duplicate of every nut and bolt.

A set of coupling bolts.

A suitable coupling for patching a broken propeller shaft.

If ball races are used, a duplicate should be carried

Starting.

All engines that cannot be properly started by one man must be provided with some kind of automatic starting gear.

Huntingdon Bay, the scene of the B.I. Trophy race of 1908. "Wolseley-Siddeley," "Daimler II.," and "Dixie II." can be seen at their moorings.

INTERNATIONAL MOTOR YACHT RACING ASSOCIATION.

During 1908 an International Association for the regulation of regattas where international events take place was formed, and to-day it includes representatives of practically all countries where marine motoring is taken seriously. One or two details relating to systems of national representation on this Association and other points in reference to its composition are still undecided as we go to press, and so nothing is to be gained by discussing questions of constitution. It may, however, be said that the Association represents the first serious attempt to place international racing on a satisfactory basis, and that this object has been very well attained. The work of the Association includes the formation of racing and rating rules, under which all international events must take place, at the same time leaving home events and club races quite free from restrictions. For the current year and the following year a system of rating has been adopted, based on last year's Monaco rules, and we give below all the essential points of these regulations, though it must be understood that the text is not official.

International classes are divided into two main sections—Racers and Racing Cruisers.

Of the former class there are two subdivisions, the first being restricted to boats not exceeding 15 metres (50ft.) in length and fitted with a four-cylinder engine of 155mm. bore or the equivalent.

The following table gives the corresponding bores for other numbers of cylinders :—

No. of Cylinders.	Bore in Millimetres.
1	310
2	219
3	179
4	155
6	127
8	110

In the second racer class the only restriction is the length of the hull, which, as in the other class, must not exceed 15 metres; engines of any power may be installed.

Racing Cruisers.

The racing cruisers are classified, as they have always been at Monaco, according to length and power, these classes being as follow :—

Class I.—Dinghy class, fitted with a single-cylinder engine of 100mm. bore or the equivalent, not exceeding 6½ metres in length and weighing complete not less than 650 kilograms.

Class II.—Not exceeding 6½ metres in length and fitted with four-cylinder engines of 85-90mm. bore or the equivalent.

Class III.—6½ to 8 metres in length and fitted with four-cylinder engines of 100-106mm. bore or the equivalent.

Class IV.—8 to 12 metres in length and fitted with four-cylinder engines of 120-130mm. bore or the equivalent.

Class V.—12-18 metres in length and fitted with four-cylinder engines of 140-155mm. bore or the equivalent.

Hulls.

There is a restriction on beam, freeboard and seating accommodation in each class, these dimensions varying according to the length. If the length in metres be denoted by L, the greatest beam must be not less than $0.60 + \frac{L}{8}$ metres, and the freeboard with the boat in racing trim must not be less than $0.20 + 0.03$ L metres, coamings not counting as freeboard. The number of passengers carried, inclusive of helmsman and engineer, is always supposed to be one less than the length of the boat in metres, each fraction of a metre counting as a complete metre, and seating accommodation for this number must be provided to the extent of 0.45 of a metre in every direction.

N.B.—Beam and freeboard calculations with this formula must be made in metres.

Power Rating.

A complication arises in finding the equivalent bores of engines having different numbers of cylinders, for power under the new rule is calculated for the racing cruisers, not simply on piston area, that is, according to the square of the bore, but according to the 2.4 power of the bore, the idea being to give a slight advantage to small cylinders. Under a simple piston area rule, they are rather handicapped against larger motors.

To find the equivalent bore, let us say of a six-cylinder engine, to give the same power rating as a four-cylinder motor of a certain size, involves, therefore, a calculation necessitating the use of logarithms, but, to simplify this work for the reader, we have prepared a curve, which we publish herewith, and which will enable anyone with a little practice to find the equivalent bore for an engine of any number of cylinders. The upper horizontal scale represents bores in millimetres. Suppose it is desired to find the bore of a six-cylinder engine equivalent to that of a four-cylinder motor of 106mm. The figure 106 is looked up on the scale, and from this

point a line is run vertically to cut the sloping lines marked at the top "number of pistons." The figure "4" indicates the four-cylinder line, and the vertical line just referred to is drawn to cut this line. A horizontal line is drawn from the point of intersection to the left till it cuts the six-cylinder line. If from this latter point a vertical line be dropped on to the upper hori-zontal scale a reading will be obtained just under 90mm., so that we may say the equivalent bore of a six-cylinder engine is 89.5mm.

Weights.

The question of weights must now be considered, but in order to understand them properly a short explanation will be necessary. A rating formula of the following form has been adopted:—

$$R = \frac{n\,D^{2.4}}{P^{1/3}}$$

Where R = the rating
n = number of cylinders.
D = cylinder bore in millimetres.
P = weight in 1,000 kilogram units (French tons).

Under this rule a certain rating is fixed for each of the racing cruiser classes. Arbitrary limits of engine bore are chosen and from these the weights can be calculated, these weights representing the figures at which the boat must race; thus, if a small engine be chosen, the racing weight of the boat will be less than if a larger one be installed. The following table gives the racing weights in the classes to which they apply, corresponding to four-cylinder engines of the bores stated. N.B.—The dinghy class is not included in this series.

CLASS II.—NOT EXCEEDING $6\frac{1}{2}$ METRES.

$$R = 206{,}000 = \frac{4\,D^{2.4}}{P^{1/3}}$$

D = bore in Millimetres.	P = weight in racing trim (kilograms).
85	755
86	788
87	821
88	856
89	891
90	930

CLASS III.—$6\frac{1}{2}$-8 METRES IN LENGTH.

$$R = 242{,}000 = \frac{4\,D^{2.4}}{P^{1/3}}$$

D = bore in Millimetres.	P = weight in racing trim (kilograms).
100	1,065
101	1,104
102	1,143
103	1,185
104	1,221
105	1,270
106	1,314

CLASS IV.—8-12 METRES IN LENGTH.

$$R = 315{,}000 = \frac{4\,D^{2.4}}{P^{1/3}}$$

D = bore in Millimetres.	P = weight in racing trim (kilograms).
120	1,382
121	1,424
122	1,467
123	1,511
124	1,556
125	1,601
126	1,648
127	1,696
128	1,744
129	1,794
130	1,844

CLASS V.—12-18 METRES IN LENGTH.

$$R = 360{,}000 = \frac{4\,D^{2.4}}{P^{1/3}}$$

D = bore in Millimetres.	P = weight in racing trim (kilograms).
140	1,971
141	2,022
142	2,074
143	2,127
144	2,181
145	2,256
146	2,292
147	2,349
148	2,407
149	2,467
150	2,527
151	2,588
152	2,650
153	2,713
154	2,778
155	2,843

In all these cases the weights include the weight of passengers, but do not include spare parts, petrol or lubricating oil. There is, of course, nothing to prevent a boat racing over her rated weight, but she must not start at a lower figure. To ensure a reasonable degree of strength of construction a minimum weight limit is also fixed for the hull and engine alone, exclusive of crew and of fuel, etc., which may be found from the curve given herewith in a way that will be explained later. Passengers are reckoned at 70 kilograms each, and in place of actual people ballast may be carried in a race, though the seating accommodation must still be provided. In order, however, to encourage the building of a robust type of boat, it is permitted to build the boat considerably heavier than the minimum limit and to knock this weight off the quantity of passenger ballast carried.

Take, for example, an extreme case of an 8-metre racing cruiser with a 106mm. engine, her racing weight is 1,314 kilograms and the minimum weight for hull and engine alone is about

800 kilograms, the difference being made up with seven passengers, but it is only compulsory to carry a helmsman and engineer weighing between them 140 kilograms. If we subtract this weight from the racing weight, we get 1,174 kilograms as a remainder, and if the boat and engine alone be built right up to this weight, no ballast at all need be carried.

With this explanation, we will turn to the more nearly horizontal set of lines in the curve; it will be noticed they are eight in number, the four full lines from bottom to top being the ratings without passengers of the racing cruiser classes from II. to V., the dotted lines are ratings of the same classes, including passengers. We will take again our eight-metre boat fitted with 106mm. four-cylinder engine. Look up 106mm. and run a vertical up to the four-cylinder line, as already described. To find the racing weight of the boat, including passengers, a horizontal line is then drawn to the line marked R = 242,000. If a vertical line be dropped from this point of intersection, it will give on the lower horizontal scale the same racing weight already stated, viz., 1,314 kilograms. Now, suppose the weight of the hull and boat alone, without passengers, be required: a horizontal line is drawn to cut the continuous rating line marked R = 340,000. A vertical line dropped from this point gives a reading of just over 800 kilograms, which is, therefore, the minimum weight of the boat. The use of these curves may appear a little complicated at first, but the reader will soon become used to them, and once mastered they will be found far more handy than any table for working out equivalent engine bores, or for finding the corresponding weights.

The above is by no means a complete list of the International Rules, but all the essential points are embodied, and if the rules given be adhered to, the reader will find that there is nothing else of much importance to be learned.

THE MARINE MOTOR ASSOCIATION.

The Marine Motor Association was founded in the autumn of 1902 by a number of yachtsmen and others interested in marine motor matters, and in the following year an executive council was formed to frame racing rules, etc., and to carry on the work of the Association, which, broadly speaking, was designed to encourage the development of marine motors and to promote the sport of marine motor racing. From that time onwards the Association consisted of a president, two vice-presidents, an hon. treasurer, and a council of 20 members, elected out of the ordinary members who could join as individuals on payment of an entrance fee of a guinea and an annual subscription of the same amount. Affiliated clubs also enjoyed representation on the council.

We write in the past tense because at the present moment the question of the reconstitution of the M.M.A. is under consideration. Its objects will remain the same, but instead of being an association of individual members, it is suggested, and it is almost certain that the suggestion will be carried out, that it should consist of delegates of affiliated clubs, each club being equally represented on the council, irrespective of size. The suggestion is, we think, an admirable one, and if carried out will provide an extremely powerful and representative national body for the control of the sport. Until this question of reform has been settled, it will not, of course, be possible to say exactly the part that the Association will take in international affairs, but it is to be expected that British interests in the International Motor Yacht Racing Association will be looked after by the M.M.A.

As regards national events, the Association has under consideration a power rating rule depending on exhaust valve area. The rule is in no sense a rival to the international rule, but is intended merely to facilitate the handicapping of miscellaneous boats.

In view of the constitutional changes that seem to be imminent, there is no need to give the list of officers for the last year. The secretary, however, is Mr. R. G. L. Markham, of 143, Strand, W.C.

BRITISH CLUBS.

Some particulars of most of the leading marine motoring clubs in this country will be found below. For ease of reference the list is arranged alphabetically, without reference to seniority.

British Motor Boat Club.

This club was founded in December, 1904, the object being the encouragement and advancement of motor boating and the organisation of races and cruises. To quote from its rule book, "The club is essentially a members' club. It is a society of encouragement, a social club, and a centre of information and advice on matters pertaining to boats and vessels propelled partly or solely by mechanical means."

Up to the time of the formation of this club there was no independently constituted body to promote races and such like events in this country, though there was, of course, the Marine Motor Association, whose function, however, was purely legislative, and which did not propose to concern itself with the organisation of races.

The club commenced work by organising motor-boat racing in 1905, in which year meetings were carried through at five places, chiefly in East Anglia and the Solent. In 1906 the number of meetings under the ægis of the club was increased to seven, which included the long-distance race from the Thames to Cowes for cruising motor vessels.

Since that time steady progress has been made, and the yearly programme is now a very full one, the places visited including Oulton Broad, Lowestoft, Gravesend, Burnham-on-Crouch, Cowes, Ryde, Southsea, etc. In future the international classes will probably be provided for at the most important meetings, and, besides these and the ordinary races, a special club class for boats and hydroplanes will make its appearance next season.

In 1907 a very notable amalgamation was effected by the club with the Motor Club, by which B.M.B.C. members acquired the use of the extremely comfortable M.C. house in Coventry Street, the subscription being raised to £5 5s. for town members and £3 3s. for country members. Branches of the club were formed some time back in Ireland and on the Clyde (the latter is now self-supporting), and in that way, as well as by holding its own races in different parts of the country, the club has always pursued a policy of encouraging motor-boat racing as widely as possible. As regards its constantly varying venues, the position of the B.M.B.C. is unique in this country, all other clubs, except so far as affiliated or otherwise allied institutions are concerned, being confined more or less to one locality.

Official repairers and boat yards, where boats can be left and housed, stores supplied, and repairs done at reduced rates, have been appointed by the club at various ports round the coast and on the rivers.

Insurance of motor boats at reduced rates and with special clauses can be obtained by members.

Members of the club have the privilege of flying the Blue Ensign of his Majesty's Fleet on applying for a special warrant, this permission being granted in June, 1905.

The burgee of the club is blue with a red St. Andrew's cross edged with white.

The following is a list of officers and of the committee :—

Admiral.—Admiral Sir William Kennedy, K.C.B.

Vice-Admiral.—The Marquis of Ailsa.

Commodore.—W. Miall Green, Esq.

Vice-Commodore.—L. M. Waterhouse, Esq.

Rear-Commodore.—F. May, Esq.

Hon. Treasurer.—Oswald B. Colls, Esq.

Secretary.—R. B. Robinson.

Committee.—The officers and J. F. Avila, Esq., F. C. Blake, Esq., Mawdsley Brooke, Esq., P. Bonthron, Esq., Col. W. J. Bosworth, J. Day, Esq., A. Harden, Esq., N. B. Kenealy, Esq., C. Jarrott, Esq., L. Miles, Esq., G. de Holden Stone, Esq., K. O. Searle, Esq., L. Schlentheim, Esq., A. W. Robinson, Esq.

Secretary.—R. B. Robinson, Esq., Prince's Buildings, Coventry Street, W.

Thames Quarters.—Nuttall's, Kingston-on-Thames.

IRISH BRANCH.

Hon. Secretary.—W. Scott Hayward, Esq., Silverstream, Co. Antrim.

Clyde Motor Boat Club.

Among the most recently formed marine motor clubs in the country is the Clyde Motor Boat Club. It only came into existence in the spring of 1908, being formed in Glasgow during May by a number of Clyde motor-boating men. The special objects of the club are officially stated to be as follows:—

1. To encourage motor boating and motor-boat racing on the Clyde.
2. To encourage week-end cruises.
3. To give races for any classes of boats.
4. To hold inter-club races.
5. To hold social meetings in the off season in order to keep the interests of the club alive.

Only three weeks after the formation of the club a very successful regatta was held at Hunters' Quay, the headquarters of the club, and subsequently races were held at several other places, there being six meetings in all. Altogether, the club may be said to have had a very successful opening season.

The officers and committee for the year were the following:—

Hon. Treasurer.—G. Egerton Pipe, Esq.

Committee.—R. J. Dobbie, Esq., G. F. McLachan, Esq., J. A. McCallum, Esq., D. Primrose, Esq., Thos. F. Taylor, Esq.

Hon. Secretary.—J. R. Cameron, Esq., 52, Lawrence Street, Dowan Hill, Glasgow.

Last year the entrance fee and subscription were each 5s., but with a rapidly-increasing membership this will probably be raised in 1909.

Burgee.—The burgee of the club is white with a blue St. George's Cross and a yellow "C" in the middle.

Essex Motor Boat Club.

The Essex Motor Boat Club was founded on July 17th, 1907, the headquarters being the Nore Yacht Club, Southend. Since its formation the club has been well supported by the B.M.B.C., and, with the help of that body, has in the year-and-a-half of its existence organised two very successful open regattas, besides providing races for its members on most week-ends of the season. In 1909 it is proposed particularly to encourage cabin cruisers by providing several long-distance events for that class of vessel, a project that should meet with success, as about a dozen boats of the type are already included in the club's fleet.

The club is enabled to make use of Southend Pierhead for the purpose of starting its races, thereby affording unrivalled spectacular advantages, while Hole Haven near by provides a very convenient mooring ground for the competing boats. A measured half-mile is being marked out alongside the pier, and in 1909 it is intended to hold speed trials over this course, in addition to other events.

Members of the E.M.B.C. enjoy privileges of membership of the Nore Y.C.

The following is a list of officers and the committee for 1908.

Admiral.—Admiral Sir William Kennedy, K.C.B.

Commander.—A. D. Goodacre, Esq.

Vice-Commander.—W. G. Tarbet, Esq.

Race Officer.—W. E. Boosey, Esq.

Committee.—J. Dring, Esq., G. Gilson, Esq., H. J. Hayward, Esq., A. T. Kerr, Esq.

Hon. Secretary and Treasurer.—A. H. Phillips, Esq., 3, Herbert Grove, Southend-on-Sea.

The burgee of the club is red with a three-bladed propeller on a white ground.

Motor Yacht Club.

The Motor Yacht Club was inaugurated in December, 1902, in the form of a branch of the Royal Automobile Club, and under the title of the Marine Motor Committee. Its object was, and is, further to develop the interests of marine motoring in every direction possible. It interests itself in the progress of motor power as applied to sport, both in racing and cruising vessels, to commercial work, and to its adoption and use by the Admiralty for service in the Navy.

The first event of importance controlled by the Club was the race for the Harmsworth Cup, held at Queenstown in June, 1903.

The following year this race attracted five French and two American entries.

It was in this year that the reliability trials for motor boats were commenced, and the first of the series was held in Southampton Water in July. Twenty-six entries were received, comprising vessels of many and varied types.

In May, 1905, the title of the Motor Yacht Club was assumed, and a further step towards the decentralisation from the parent club was taken by the election from the committee of club officers. Sir Boverton Redwood was elected as vice-commodore, Commander Mansfield Cumming as rear-commodore, and Mr. Lionel de Rothschild as treasurer. Later on, the Duke of Sutherland was elected as commodore, and Mr. F. P. Armstrong as chairman of committees. In January, 1906, the Lords Commissioners of the Admiralty granted the warrant for wearing the Blue Ensign.

A team to represent the club in the race for the cup won by France the year before, and now known as the "British International Trophy," having been selected by eliminating races off Bembridge and Hythe, three boats were taken over to Arcachon in September, and the cup was brought back by Lord Montagu and Mr. Lionel de Rothschild.

Among the more important of the club events for the year should be mentioned the Calais-Dover race and the regatta held on the occasion of the visit of the French fleet.

In September of 1905, the ex-Admiralty yacht "Enchantress" was purchased for the club, and work was commenced on her to increase her accommodation and fit her for the duty of its flagship. She was opened as a clubhouse in May, 1906, a large number of the Press and many well-known figures in the motor world coming down to Southampton to give her a good send-off. The ship has proved an unqualified success for the purpose for which she has been fitted up, and it is hoped that she has a long and useful career in front of her. She is by no means an old vessel, and as she was built in the most substantial manner and of the very best materials obtainable, there is no doubt she will last indefinitely, so far as wear and tear are concerned. The ship has accommodation for a large number of members to sleep on board, besides dining, smoking, and drawing-rooms, and a concert room large enough to seat 500 people. She has all the appointments of an up-to-date floating clubhouse.

At the end of 1908 Mr. J. W. Fernie was obliged to resign his position as secretary owing to ill-health, and, at the moment of writing, the post has yet to be filled. In the same year a prominent part was taken by the club in the formation of the international authority, to which reference is made elsewhere, and in that connection the eight-metre racing cruiser class was taken up, representing the first attempt to encourage motor-boat restricted class racing in this country. The experiment met, and is meeting, with very great success, and, in addition to the international classes and races for boats of other types, the 1909 season will witness some exciting sport in the club hydroplane class.

After being brought back from Arcachon, the B.I. Trophy was carried off to America in 1907 by "Dixie." In 1908 the club sent two challengers, "Wolseley-Siddeley" and "Daimler II.," across the Atlantic, but the defending boat, "Dixie II.," prevented the trophy coming back to this country, for another year at any rate.

The entrance fee and subscription are each three guineas, but it is possible that the former may be raised ere long, as the new R.A.C. premises will probably include club rooms for the M.Y.C., whereby a footing will be obtained in London, in addition to the headquarters at Netley. During the winter the "Enchantress" was moved from her moorings up the Hamble River, where she will remain until the commencement of next season. Her presence there is doing much to encourage some measure of activity during what is usually called the "slack" season.

The flag officers and committee for 1908 were the following :—

Commodore.—The Duke of Sutherland, K.G.

Vice-Commodore.—Lord Montagu of Beaulieu.

Rear-Commodore.—Comdr. Mansfield Cumming, R.N.

Chairman of Committees.—F. P. Armstrong, Esq.

Hon. Treasurer.—Lionel de Rothschild, Esq.

Committee.—F. P. Armstrong, Esq., F. R. S. Bircham, Esq., F. H. Butler, Esq., E. J. Caldbeck, Esq., Lorne C. Currie, Esq., Capt. R. T. Dixon, R.E., Comdr. Sir H. D. Freer-Smith, R.N., H. Western Hutchinson, Esq., G. Knowles, Esq., A. G. New, Esq., G. Foster

Pedley, Esq., Bernard Redwood, Esq., J. A. Rennie, Esq., G. Sharp, Esq., J. D. Siddeley, Esq., L. R. L. Squire, Esq., T. Thornycroft, Esq., Hon. A. Verney Cave, Major S. F. Warren, T. D. Wynn Weston, Esq.

Secretary.—J. W. Fernie, Esq., "Enchantress," Netley Abbey, Bursledon, Southampton.

The club burgee has one white and two blue horizontal stripes with a red three-bladed propeller in the centre.

IRISH BRANCH.

The Irish branch of the M.Y.C. has its headquarters at the Automobile Club, Dawson Street, Dublin.

Hon. Treasurer.—W. Barrett, Esq.

Committee.—H. Heap, Esq., D. Turner, Esq., Col. Peyton, Dr. Peyton, and Scott Hayward, Esq.

The burgee is the same as that of the parent club, with the addition of a shamrock.

Sussex Motor Yacht Club.

The Sussex Motor Yacht Club, founded on April 4th, 1907, under the name of the Sussex Motor Boat Club, is the largest after the M.Y.C. and B.M.B.C. in the British Isles. The headquarters of the club are at Brighton, where, in each year of its existence, a first-class three-day regatta has been held, besides Saturday events for members.

Up to almost the end of 1908 the headquarters were at the Grand Hotel, Brighton, but club rooms have now been obtained at Middle Street, King's Road, while a special feature is the admittance of ladies as members at a subscription of £1 1s., giving the right to take part in club races, etc., and the use of the club premises on such days and at such times as the committee may decide.

The club is affiliated to the M.Y.C., the members of the two clubs being privileged to enter for races given by either, without extra entrance fee, and it was in connection with this arrangement that the change of name above referred to was made during 1908. In that year also a race took place from the "Enchantress" to Brighton, there being a return race after the S.M.Y.C. Regatta. In addition, it may be noted that members of the Sussex Club are enabled to make use of the "Enchantress" for certain periods.

The following were the officers and committee for 1908:—

Commodore.—Right Hon. Viscount Curzon, R.N.V.

Vice-Commodore.—Sir Theodore Angier, R.N.V.

Rear - Commodore.—Lieut. O. Sumner, R.N.R.

Committee.—P. Barca, Esq., Ald. Bruce Morison, J.P., Baron Von Bissing, C. M. Brown, Esq., W. G. A. Edwards, Esq., H. J. Preston, Esq., Dr. B. Mends, R.N., Captain F. V. Pryor, J. S. Smith, Esq., W. Pearce, Esq., W. Patten, Esq., G. Hill, Esq., T. Reeves, Esq.

Secretary.—H. J. Mann.

Burgee.—The club burgee is blue with six martlets and a three-bladed propeller on a white shield.

The annual subscription is £2 2s.

Thames Valley Launch Club.

This club was formed in 1907 for the purposes of protecting the interests of and promoting social intercourse among launch owners on the Thames. In its early days the headquarters were at Teddington, but in 1908 a move was made up river to Hampton Court, where the houseboat "La Bohème" was purchased and stationed.

Obviously, races on the Upper Thames are out of the question, but the club exists rather for the social side of the pastime, and the advantages of a houseboat as headquarters may be readily appreciated, comprising, as "La Bohème" does, a good-sized saloon and extensive sleeping accommodation. Week-end cruises and meetings, besides dinners and concerts, are included in the club's programme.

The officers and committee are made up of the following:—

Commodore.—Col. Sir Albert Kaye Rollit.

Rear-Commodore.—R. Bamford Smith, Esq.

Committee.—J. R. Boger, Esq., G. R. Burgess, Esq., H. Hopkins, Esq., G. Filmer, Esq., J. A. Kingston, Esq., O. H. Oertel, Esq.

Hon. Secretary.—F. G. Rogers, Esq., 151, Oxford Street, London.

Burgee.—The club burgee is red with a steering wheel and the initials T.V.L.C. in white.

The annual subscription is £2 2s.

TABLES AND FORMULÆ.

General Tide Tables.

Showing the time to be added to, or subtracted from, the times of High Water at London Bridge, to find the times of High Water at the respective places; also the times of High Water on the Full and Change of the moon (or establishments of the ports), with the rise of water at Spring or Neap Tides in

ENGLAND AND WALES.

London Bridge.	Places.	Full and Change.	Rise. Spr	Rise. N.
H. M.		H. M.	FT.	FT.
Add 5 34	Aberystwyth	7 31	18½	10
Add 2 33	Agnes', St., Light, Scilly	4 30	16	12
Add 8 57	Air Point, River Dee	10 54	25	19
Add 8 48	Aldborough Bay	10 45	8	6½
Add 4 49	Alderney	6 46	17	12½
Add 3 59	Ann's St., Light, Milford	5 56	24	18
Add 9 10	Ayr Point, Isle of Man	11 7	20	16
Add 5 44	Barmouth	7 41	17	13½
Add 9 35	Barrow	11 32	31½	24
Add 3 33	Barnstaple Bar	5 30	19	14
Add 9 23	Beachy Head	11 20	20	15
Add 8 35	Beaumaris	10 32	21½	16½
Add 0 21	Berwick Bar, 9ft. less than Shields	2 18	15	11½
Add 4 10	Bideford	6 7	16	12
Add 5 3	Boston Deep (Sluice)	7 0	12	
Add 4 8	Bridport	6 5	11½	7½
Add 5 16	Bristol, Cumberland Dock Entrance	7 13	31½	
Add 9 20	Calf of Man	11 17	16¼	13
Add 9 20	Calf Sound	11 17	16¼	13
Add 9 33	Calshot (Castle Point)	11 30	13	9½
Add 5 2	Cardiff (High Water spring tides 42ft.).	6 59	38	29
Subt. 3 19	Cowes	10 45	12½	9½
Add 7 36	Carnarvon Bar	9 33	18½	10½
Add 3 47	Caermarthen Bar, Wales	5 44	26	19½
Add 7 3	Christchurch, Hants.	9 0	5	
Subt. 0 55	Chatham	1 2	17½	14
Add 2 38	Cornwall (Cape)	4 35	18	18
Add 5 3	Cromer	7 0	14¾	11
Add 4 19	Dartmouth	6 16	14¼	10½
Add 9 18	Deal	11 15	16	12½
Add 9 15	Douglas, Isle of Man	11 12	20¾	16
Add 9 15	Dover	11 12	18¾	15
Add 0 48	Downs	2 45	15	
Add 8 48	Dungeness	10 45	21¾	19
Add 3 18	Eddystone	5 15	16	12
Add 4 24	Exmouth Bar, 11ft. less than Shields	6 21	12½	8
Add 3 0	Falmouth	4 57	16	12
Add 2 23	Filey Bay	4 20	16	12½
Add 2 33	Flambro' Head	4 30	16	12
Add 9 14	Fleetwood	11 11	27	20½
Add 9 10	Folkestone	11 7	20	16½
Add 9 48	Foreland, North	11 45	10	7
Add 9 23	Foreland, South	11 20	18	10
Add 8 38	Formby Point	10 35	24	19
Add 9 48	Galloper	11 45		
Subt. 0 30	Goodwin, back of	1 27		
Add 5 47	Goole, Humber	7 26	13	
Subt. 0 47	Gravesend	1 10	17½	14
Subt. 0 14	Greenwich	1 43	19	15
Add 3 39	Grimsby	5 36	19½	15
Add 9 43	Gunfleet Sand, N.E. end	11 40	12	8
Add 1 31	Hartlepool Bar	3 28	15	11¾
Subt. 1 51	Harwich, within	0 6	11½	9¾
Add 8 56	Hastings	10 53	24	17½
Add 9 3	Helens, St.	11 0		
Add 2 46	Helford, entrance	4 43	15½	11½
Add 0 33	Holy Island Harbour	2 30	15	11½

ENGLAND AND WALES—*(continued.)*

London Bridge.	Places.	Full and Change.	Rise. Spr	Rise. N.
H. M.		H. M.	FT.	FT.
Add 8 14	Holyhead Bay	10 11	16	12½
Add 4 32	Hull	6 29	20¾	16½
Subt. 1 22	Ipswich, 9½ft. less than Shields	0 35	15	
Add 9 26	Liverpool Dock	11 23	26	20½
Add 3 3	Lizard Point	5 0	14¼	10½
Subt. 0 4	London Docks	1 53	19½	17
0 0	London Bridge	1 57	19¼	16
Add 2 38	Longships	4 35	20	14
Add 8 0	Lowestoft Road	9 57	6½	5½
Add 3 18	Lundy Island	5 15	27	20
Add 4 24	Lyme Regis	6 21	11½	8½
Add 4 3	Lynn Deeps, Long Sand	6 0	23	
Add 5 33	Madoc Port	7 30	17	
Subt. 1 52	Maplin Light	0 5	14½	10½
Add 9 43	Margate Roads	11 40	15½	13
Add 9 6	Maryport	11 3	18	13
Add 3 59	Milford Haven	5 56	24	18
Add 9 3	Nab Light	11 0	14	
Subt. 1 51	Naze, Essex	0 6	12½	10
Add 7 49	Needles Point, Isle of Wight	9 46	7½	5
Add 2 26	Newcastle Quay	4 23	10¼	
Add 9 54	Newhaven	11 51	20	15
Add 5 13	Newport	7 10	38	29
Subt. 1 27	Nore Light	0 30	15½	13
Add 9 18	Orfordness, off	11 15	8	6½
Add 9 3	Owers	11 0	15	
Add 9 8	Peel Harbour (Pier)	11 5	28	21
Add 9 11	Peel	11 8	16¼	13
Add 4 15	Pembroke Dockyard	6 12	21	15½
Add 2 33	Penzance	4 30	16¼	12½
Add 3 40	Plymouth Breakwater	5 37	15½	11½
Add 7 13	Pool Bar, first flood	9 10 / 12 45	6½	4¾
Add 5 4	Portland Breakwater	7 1	6¾	4½
	„ Race	9 15		
Add 9 44	Portsmouth Dockyard	11 41	13½	10
	„ Offing, Spithead	9 30		
Add 9 15	Ramsey	11 12	19½	16
Add 9 47	Ramsgate Harbour	11 44	15	12
Add 8 54	Ribble Lighthouse	10 51	24	17
Add 9 23	Ryde	11 20	18¾	
Add 2 14	Scarbro' Pier	4 11	15¾	12½
Add 2 33	Scilly Island, St. Agnes	4 30	16	12
Add 4 33	Scilly Island, St. Agnes offing	6 30		
Add 1 27	Seaham Harbour	3 24	14½	10½
Subt. 1 20	Sheerness	0 37	16	13¼
Add 9 37	Shoreham	11 34	18	13¼
Add 4 3	Smalls Lighthouse	6 0	21	
Add 8 33 / Add 10 48	Southampton	10 30 / 12 45	13	9½
Add 7 33	Spithead	9 30		
Add 3 44	Start Point	5 41	15	11
Add 7 3	but off it	9 0		
Add 1 25	Sunderland	3 22	14½	10
Add 0 33	„ North	2 30	15	11½
Add 4 4	Swansea, Mumbles Light	6 1	27½	20¼
Add 10 3	Swin, through it	12 0		
Add 9 25	Tarn Point	11 22	28	18
Add 1 48	Tees Bar, 3ft. 3in. less than Shields	3 45	15	12½
Add 4 3	Teignmouth	6 0	13	9½

General Tide Tables—continued.

ENGLAND AND WALES—(*continued.*)

London Bridge.			Places.	Full and Change.		Rise.	
	H.	M.		H.	M.	Spr. FT.	N. FT.
Add	8	45	Tenby	5	42	27	20
Add	4	8	Torbay	6	0	18½	10
Add	1	23	Tynemouth Bar	8	20	14¾	11¼
Add	4	23	Wells Bar	6	20	18	
Add	5	8	Wells	7	0		
Add	5	8	Weymouth Bar	7	0	7	5
Add	1	48	Whitby Bar	3	45	15	11½
Add	9	17	Whitehaven	11	14	23½	18¾
Add	5	33	Wisbeach	7	30	15	
Subt.	1	47	Wivenhoe	12	10	15	10½
Subt.	0	20	Woolwich	1	37	18½	15½
Add	9	7	Workington	11	4	20	15
Add	7	18	Yarmouth Roads	9	15	6	4½
Add	8	33	Outside	10	30		
Add	8	8	Yarmouth, Isle of Wight	10	0	7	6½
Add	10	8		12	0		

COAST OF SCOTLAND, ORKNEYS, ETC.

London Bridge.			Places.	Full and Change.		Rise.	
	H.	M.		H.	M.	Spr. FT.	N. FT.
Subt.	0	57	Aberdeen	1	0	12	10
Add	1	21	Alloa, Firth of Forth	3	18	17½	15
Subt.	0	22	Arbroath	1	35	14	11
Add	9	48	Ardrossan	11	45	10	8
Add	0	27	Burntisland, Firth of Forth	2	24	16½	12¾
Add	8	8	Caithness Point	10	0	9	4
Add	8	33	Cantire, Mull of	10	35	4	
Add	9	59	Cromarty	11	56	14	11
Subt.	1	37	Dumbarton	0	20	9	
Add	0	35	Dundee Pier	2	32	14½	11½
Subt.	1	17	Fraserburgh	0	40	11	8
Add	9	18	Galloway, Mull of	11	15	15	12
Subt.	0	32	Glasgow	1	25	9	7½
Add	0	50	Grangemouth	2	47		
Add	0	23	Granton Pier	2	20	16	12½
Subt.	1	49	Greenock	0	8	9¾	8½
Add	10	21	Inverness Firth, Kessock	12	18	12	9½
Add	8	12	Kirkwall Road	10	9	10	7½
Add	9	52	Lamlash	11	49	10	7
Add	0	20	Leith	2	17	16½	12¾
Add	3	24	Oban	5	22	12	9½
Add	8	33	Pentland Firth	10	30	9	6
Add	7	50	„ Stroma, S. Side	9	47	7½	6
Add	8	27	„ Swona, E. Side	10	24	10	7½
Add	7	38	„ Swona, W. Side	9	35	10	7
Add	9	7	„ Great Skerry, East Side	11	4	7¾	6½
Add	8	56	„ Great Skerry, West Side	10	58		
Subt.	1	39	Port Glasgow	0	18	9	
Add	7	33	Scalloway, Shetland	9	30	5¾	4½
Add	4	49	Stornoway	6	46	13½	9½
Add	7	3	Stromness	9	0	10	7½
Add	7	48	Sumburg Head, Shetland	9	45		
Add	0	9	Tay Bar	2	6	16	14
Add	9	25	Tarn Point, Solway	11	22	23	18
Add	9	25	Wick	11	22	10	7½
Add	5	33	Wrath, Cape	7	30	15½	

COAST OF IRELAND.

London Bridge.			Places.	Full and Change.		Rise.	
	H.	M.		H.	M.	Spr. FT.	N. FT.
Add	6	48	Arklow	8	45	4	3
Add	3	21	Ballyshannon Bar	5	18	11½	8½
Add	1	50	Bantry Harbour	3	47	10	8
Add	8	46	Belfast	10	43	9½	
Add	9	8	Carlingford Bar	11	10	14	
Add	2	3	Clear, Cape	4	0	9	6½
Add	3	1	Cork, Penrose Quay	4	58	12¾	10
Add	9	16	Donaghadee	11	13	11½	9½

COAST OF IRELAND—(*continued.*)

London Bridge.			Places.	Full and Change.		Rise.	
	H.	M.		H.	M.	Spr. FT.	N. FT.
Add	3	21	Donegal Harbour	5	18	11½	8½
Add	9	3	Drogheda Bar	11	0	11½	9
Add	9	15	Dublin Bar	11	12	14	11½
Add	8	59	Dundalk	10	56	18½	11
Add	2	38	Galway	4	35	14½	11
Add	9	12	Howth Harbour	11	9	13	10
Add	9	13	Kingstown	11	10	11	8½
Add	2	46	Kinsale	4	43	11½	9
Add	6	4	Londonderry	8	1	7¾	5½
Add	8	56	Lough Strangford	10	53	14	11½
Add	3	4	Queenstown	5	1	11½	9
Add	3	45	Rathmullen, Lgh. Swilly	5	42	12½	9
Add	3	43	Saltees	5	40		
Add	2	19	Shannon River, Kilbaha	4	16	13	9½
Add	2	45	„ Kilrush	4	42	14	10½
Add	3	38	„ Foynes Is.	5	35	15½	12
Add	4	4	„ Mellon	6	1	18½	13½
Add	4	19	„ Limerick	6	16	18½	13½
Add	9	3	Sherries Island	11	0	13	10
Add	3	21	Sligo Bay	5	18	11½	8½
Add	1	45	Valentia Harbour	3	42	11	8
Add	3	23	Waterford, Duncannon Fort	5	20	12½	10
Add	4	9	Waterford Bridge	6	6	13½	10½
Add	3	0	Westport	4	57	12½	9½
Add	5	24	Wexford	7	21	5	3½
Add	8	32	Wicklow	10	29	9	6½
Add	3	17	Youghall	5	14	12½	10

COAST OF FRANCE.

London Bridge.			Places.	Full and Change.		Rise.	
	H.	M.		H.	M.	Spr. FT.	N. FT.
Add	4	49	Alderney Island, West Point	6	46	17	12½
Add	5	54	Barfleur	8	51	17	13½
Add	4	53	Bordeaux	6	50	14	12½
Add	9	28	Boulogne	11	25	25	19
Add	1	50	Brest	3	47	19	14
Add	9	52	Calais	11	49	19½	15½
Add	5	52	Cherbourg	7	49	17	12½
Add	9	9	Dieppe	11	6	27	20½
Add	10	11	Dunkirk	12	8	16½	13½
Add	9	30	Grisnez, Cape	11	27	21½	16½
Add	4	40	Guernsey, St. Peter Port	6	37	26	18½
Add	7	54	Havre de Grace	9	51	22	18
Add	6	45	Hougue, Cape La	8	42	18½	14½
Add	7	32	Honfleur	9	29	23½	18
Add	4	18	Jersey, Rosel	6	15	30	21½
Add	4	39	Jersey, St. Helier	6	36	31½	23
Add	4	8	Malo, St.	6	5	35	26
Add	1	13	Nazaire, St.	3	10	15½	11
Add	1	35	Ushant	3	32	19½	13½
Add	9	49	Vallery, pt. River Somme	11	46	27	21½

HOLLAND, BELGIUM, GERMANY, ETC.

London Bridge.			Places.	Full and Change.		Rise.	
	H.	M.		H.	M.	Spr. FT.	N. FT.
Add	3	22	Altona, River Elbe	5	19	7	
Add	2	28	Antwerp	4	25	15	
Add	1	3	Bremen, Lightvessel	3	0		
Add	0	33	Brielle, Bar or Flat	2	30		
Subt.	1	57	Elbe, Entrance	12	0	11	
Subt.	0	37	Flushing	1	20	15	
Add	9	36	Heligoland	11	33	9½	7
Add	10	21	Nieuport	12	18	15	
Subt.	1	32	Ostend	0	25	19	13
Add	1	48	Rotterdam	3	45	7	
Add	3	59	Skaw	5	56		
Add	4	33	Texel, outside shoals	6	30	4	3
Add	5	48	„ Road	7	45		
Add	9	33	Weser, outer Lightvessel	11	30		

Speed from Time over Unit Distance.

From the following tables the speed of a boat can be at once read off against the time taken to run over a measured distance. The tables are equally applicable to statute miles, nautical miles, or kilometres; thus if the measured distance be 1 kilometre, the speed will be given in kilometres per hour, if the distance be a nautical mile, the speed will be in knots, &c. If the distance be only half a mile, &c., then the corresponding speed figure in the table must be halved to find the correct speed of the boat per hour. The third figure of decimals must not be accepted as entirely accurate.

Table I.

Speeds from 30 to 15. Times in fifths of a second.

Secs.	5ths.	2min.	3min.	Secs.	5ths.	2min.	3min.	Secs.	5ths.	2min.	3min.	Secs.	5ths.	2min.	3min.
0	0	30·000	20·000	15	0	26·667	18·481	30	0	24·000	17·143	45	0	21·818	16·000
	1	29·950	19·978		1	·628	·442		1	23·968	·127		1	·792	15·986
	2	·901	·956		2	·589	·423		2	·936	·111		2	·766	·972
	3	·851	·934		3	·549	·405		3	·905	·094		3	·739	·957
	4	·802	·912		4	·510	·386		4	·873	·078		4	·713	·943
1	0	·752	·890	16	0	·471	·367	31	0	·841	·062	46	0	·687	·929
	1	·703	·868		1	·432	·344		1	·810	·046		1	·661	·915
	2	·654	·846		2	·393	·326		2	·778	·030		2	·635	·901
	3	·606	·824		3	·355	·307		3	·747	·013		3	·609	·887
	4	·557	·802		4	·316	·289		4	·715	16·997		4	·583	·873
2	0	·508	·780	17	0	·277	·274	32	0	·684	·981	47	0	·557	·859
	1	·460	·758		1	·239	·256		1	·653	·965		1	·531	·845
	2	·412	·737		2	·201	·237		2	·622	·949		2	·506	·831
	3	·364	·715		3	·163	·219		3	·591	·933		3	·480	·817
	4	·316	·694		4	·125	·200		4	·560	·917		4	·455	·803
3	0	·268	·672	18	0	·087	·182	33	0	·529	·901	48	0	·429	·789
	1	·221	·651		1	·049	·164		1	·499	·885		1	·404	·775
	2	·174	·629		2	·012	·145		2	·468	·869		2	·378	·762
	3	·126	·608		3	25·974	·127		3	·438	·854		3	·353	·748
	4	·079	·586		4	·937	·108		4	·407	·838		4	·327	·735
4	0	·032	·565	19	0	·899	·090	34	0	·377	·822	49	0	·302	·721
	1	28·986	·544		1	·862	·072		1	·347	·806		1	·277	·707
	2	·939	·523		2	·825	·054		2	·316	·791		2	·252	·693
	3	·893	·501		3	·788	·036		3	·286	·775		3	·226	·680
	4	·846	·480		4	·751	·018		4	·256	·760		4	·201	·666
5	0	·800	·459	20	0	·714	·000	35	0	·226	·744	50	0	·176	·652
	1	·754	·438		1	·677	17·982		1	·196	·729		1	·151	·639
	2	·708	·417		2	·641	·964		2	·166	·713		2	·127	·625
	3	·663	·397		3	·605	·946		3	·137	·698		3	·102	·611
	4	·617	·376		4	·568	·928		4	·107	·682		4	·078	·598
6	0	·571	·355	21	0	·532	·910	36	0	·077	·667	51	0	·053	·584
	1	·526	·334		1	·496	·892		1	·048	·652		1	·028	·571
	2	·481	·313		2	·460	·875		2	·018	·636		2	·004	·557
	3	·436	·293		3	·424	·857		3	22·989	·621		3	20·972	·544
	4	·391	·271		4	·388	·840		4	·959	·605		4	·955	·530
7	0	·346	·251	22	0	·352	·822	37	0	·930	·590	52	0	·930	·517
	1	·302	·231		1	·315	·804		1	·901	·575		1	·906	·504
	2	·258	·211		2	·287	·787		2	·872	·560		2	·881	·491
	3	·213	·190		3	·250	·769		3	·843	·544		3	·857	·477
	4	·169	·170		4	·212	·752		4	·814	·529		4	·833	·464
8	0	·125	·149	23	0	·175	·734	38	0	·785	·514	53	0	·809	·451
	1	·081	·129		1	·140	·716		1	·756	·499		1	·785	·438
	2	·037	·109		2	·105	·699		2	·728	·483		2	·761	·425
	3	27·994	·088		3	·070	·682		3	·699	·468		3	·738	·411
	4	·951	·068		4	·035	·664		4	·671	·453		4	·714	·398
9	0	·907	·048	24	0	·000	·647	39	0	·642	·438	54	0	·690	·385
	1	·864	·029		1	24·966	·630		1	·614	·423		1	·666	·372
	2	·821	·008		2	·931	·613		2	·585	·408		2	·642	·359
	3	·778	18·987		3	·897	·595		3	·557	·394		3	·619	·345
	4	·735	·967		4	·862	·578		4	·528	·379		4	·595	·332
10	0	·692	·947	25	0	·828	·561	40	0	·500	·364	55	0	·571	·319
	1	·650	·927		1	·794	·544		1	·472	·349		1	·548	·306
	2	·608	·907		2	·760	·527		2	·444	·334		2	·525	·293
	3	·565	·888		3	·726	·510		3	·416	·320		3	·501	·280
	4	·523	·868		4	·692	·493		4	·388	·305		4	·478	·267
11	0	·481	·848	26	0	·658	·476	41	0	·360	·290	56	0	·455	·254
	1	·439	·828		1	·624	·459		1	·332	·275		1	·432	·241
	2	·398	·809		2	·591	·442		2	·305	·260		2	·409	·228
	3	·356	·789		3	·557	·425		3	·277	·246		3	·385	·216
	4	·315	·770		4	·523	·408		4	·250	·231		4	·362	·203
12	0	·273	·750	27	0	·490	·391	42	0	·222	·216	57	0	·339	·190
	1	·232	·731		1	·457	·374		1	·195	·201		1	·316	·177
	2	·191	·712		2	·424	·358		2	·168	·187		2	·293	·164
	3	·150	·692		3	·390	·341		3	·140	·172		3	·270	·152
	4	·109	·673		4	·357	·325		4	·113	·158		4	·248	·139
13	0	·068	·653	28	0	·324	·309	43	0	·086	·143	58	0	·225	·126
	1	·028	·634		1	·291	·291		1	·059	·129		1	·202	·113
	2	26·987	·615		2	·259	·275		2	·032	·114		2	·180	·101
	3	·947	·594		3	·226	·258		3	·005	·100		3	·157	·088
	4	·906	·576		4	·194	·242		4	21·978	·085		4	·135	·076
14	0	·866	·557	29	0	·161	·225	44	0	·951	·071	59	0	·112	·063
	1	·826	·538		1	·129	·209		1	·924	·057		1	·090	·050
	2	·786	·519		2	·097	·192		2	·898	·043		2	·067	·038
	3	·747	·499		3	·064	·176		3	·871	·028		3	·045	·025
	4	·707	·480		4	·032	·159		4	·845	·014		4	·022	·013

Speed from Time over Unit Distance—continued.

Table II.

Speeds from 15 to 12. Times in seconds.

Secs.	4min.	5min.	Secs.	4min.	5min.	Secs.	4min.	5min.	Secs.	4min.	5min.	Secs.	4min.	5min.
0	15·000	12·000	12	14·286	11·538	24	13·636	11·111	36	13·043	10·714	48	12·500	10·345
1	14·938	11·960	13	·229	·502	25	·585	·077	37	12·996	·682	49	·457	·315
2	·876	·921	14	·173	·465	26	·534	·043	38	·950	·651	50	·414	·286
3	·815	·881	15	·118	·429	27	·483	·009	39	·903	·619	51	·371	·256
4	·754	·842	16	·062	·392	28	·433	10·976	40	·857	·588	52	·329	·227
5	·694	·803	17	·008	·356	29	·383	·942	41	·811	·557	53	·287	·198
6	·634	·765	18	13·953	·321	30	·333	·909	42	·766	·526	54	·245	·169
7	·575	·726	19	·900	·285	31	·284	·876	43	·721	·496	55	·203	·141
8	·516	·688	20	·846	·250	32	·235	·843	44	·676	·465	56	·162	·112
9	·458	·650	21	·793	·215	33	·187	·811	45	·632	·435	57	·121	·084
10	·400	·613	22	·740	·180	34	139	·778	46	·587	·405	58	·081	·056
11	·343	·576	23	·688	·146	35	·091	·746	47	·544	·375	59	·040	·028

Table III.

Speeds from 10 to 6. Times in two seconds.

Secs.	6min.	7min.	8min.	9min.	Secs.	6min.	7min.	8min.	9min.	Secs.	6min.	7min.	8min.	9min.
0	10·000	8·571	7·500	6·667	20	9·474	8·182	7·200	6·429	40	9·000	7·826	6·923	6·207
2	9·945	·531	·469	·642	22	·424	·145	·171	·406	42	8·955	·792	·897	·186
4	·890	·491	·438	·618	24	·375	·108	·143	·383	44	·911	·759	·870	·164
6	·836	·451	·407	·593	26	·326	·072	·115	·360	46	·867	·725	·844	·143
8	·783	·411	·377	·569	28	·278	·036	·087	·338	48	·824	·692	·818	·122
10	·730	·372	·347	·545	30	·231	·000	·059	·316	50	·780	·660	·792	·102
12	·677	·333	·317	·522	32	·184	7·965	·031	·294	52	·738	·627	·767	·081
14	·626	·295	·287	·498	34	·137	·930	·004	·272	54	·696	·594	·742	·061
16	·574	·257	·258	·475	36	·091	·895	6·977	·250	56	·654	·563	·716	·040
18	·524	·210	·229	·452	38	·045	·860	·950	·228	58	·612	·531	·691	·020

Coastal Distances (approximate).

London to Hull 238	Glasgow to Ardrossan 48	Liverpool to Holyhead 68	Leith to Alloa 28
,, Middlesbro' 295	,, Campbelton 74	,, Douglas 70	,, Dundee 48
,, Shields 315	,, Stranraer 87	,, Dublin 124	,, Aberdeen 91
,, Leith 418	,, Belfast 116	,, Cork 254	,, Inverness 210
,, Dundee 420	,, Londonderry 140	,, Dundalk 135	,, Wick 185
,, Aberdeen 483	,, Sligo 258	,, Belfast 145	,, Berwick 52
,, Sheerness 43	,, Limerick 430	,, Londonderry 217	,, Newcastle 117
,, Dover 87	,, Dublin 197	,, Barrow 46	,, Hartlepool 128
,, South'ton 210	,, Cork 347	,, Whitehaven 73½	,, Middlesbro' 139
,, Plymouth 315	,, Liverpool 222	,, Stranraer 146	,, Hull 235
,, Cardiff 517	,, Cardiff 390	,, Ardrossan 166	,, Lynn 260
,, Liverpool 660	,, Falmouth 440	,, Cardiff 256	,, Yarmouth 291
,, Glasgow by Land's End 765	,, Southampton 582	,, Bristol 280	,, Ipswich 348
,, by Pentland Firth 949	,, Leith by Pentland Firth 630	,, Falmouth 315	,, Dover 386
,, Caledonian Cl. 815	,, Caledonian Cl. 469	,, Plymouth 346	,, Southampton 499
		,, South'ton 460	,, Falmouth 648

General Conversion Table.

In this table the equivalent quantity of the *second* denomination will be found in the column headed with the amount of the *first* denomination which it is desired to convert.

Thus, in converting 7 miles to kilometres, one would look in the line "Miles—French kilometres," and find in column 7 (corresponding to the number of miles to be converted) the equivalent number of kilometres.

Examples :— 7 miles = 11·2651 kilometres. 6 × 4 = 75·3984.

To find the equivalent of 10 times the first denomination in terms of the second denomination it is only necessary to move the decimal point in column 1 one figure to the right.

Example :— 10 French litres = 0·353156 cubic feet.

The equivalent of any other value (up to 99) of a first denomination may be obtained by moving the decimal point one figure to the right in the column corresponding to the number of tens in that value and adding the figure in the column of units.

Example :— To convert 47 avoir. lbs. to kilograms

40 lbs. = 18·14372 kilos.
7 ,, = 3·175151 ,,
47 lbs. = 21·318871 kilos.

General Conversion Table—continued.

Similarly for values of 100 and over, the decimal point would be moved two figures to the right.

The table may also be used for converting decimal parts of the first denomination, by moving the decimal point in the corresponding column one (or more, in accordance with the above system) figure to the *left*, of course interposing a "0" if necessary.

Examples:— 0·8 sq. ft. = 115·2 sq. in.

To convert 0·25 cub. yards to cub. ft.

·2 cub. yards = 5·4 cub. ft.
·05 ,, ,, = 1·35 ,, ,,
·25 cub. yards = 6·75 cub. ft.

	1	2	3	4	5	6	7	8	9
Circle.									
π	3·1416	6·2832	9·4248	12·5664	15·7080	18·8496	21·9912	25·1328	28·2744
$\pi \div 4$	·7854	1·5708	2·3562	3·1416	3·9270	4·7124	5·4978	6·2832	7·0686
2π	6·2832	12·5664	18·8496	25·1328	31·4160	37·6992	43·9824	50·2656	56·5488
4π	12·5664	25·1328	37·6992	50·2656	62·8320	75·3984	87·9648	100·5312	113·0976
Length.									
French kilometres — miles ...	·62138	1·24276	1·86414	2·48552	3·10690	3·72828	4·34966	4·97104	5·59242
Miles — French kilometres ..	1·6093	3·2186	4·8279	6·4372	8·0465	9·6558	11·2651	12·8744	14·4837
Admiralty miles — miles ...	1·1515	2·3030	3·4545	4·6060	5·7575	6·9090	8·0605	9·2120	10·3635
Miles — Admiralty miles ...	·86842	1·73684	2·60526	3·47368	4·34210	5·21052	6·07894	6·94736	7·81578
Kilometres—Admiralty miles	·539575	1·07915	1·618726	2·158302	2·697877	3·237452	3·777028	4·316603	4·856179
Admiralty miles — kilometres	1·853309	3·706619	5·559927	7·413237	9·266546	11·119856	12·973165	14·826474	16·679784
French metres — feet ...	3·2809	6·5618	9·8427	13·1236	16·4045	19·6854	22·9663	26·2472	29·5281
Feet — French metres ..	·30480	·60960	·91440	1·21920	1·52400	1·82880	2·13360	2·43840	2·74320
Inches — millimetres	25·39977	50·79954	76·19932	101·59909	126·99886	152·39863	177·79840	203·19818	228·59795
Millimetres — inches	·03937	·07874	·11811	·15748	·19685	·23622	·27559	·31496	·35·433
Square Measure.									
Sq. inches — sq. feet	·0069444	·0138888	·0208332	·0277776	·0347220	·0416664	·0486108	·555552	·0624996
Sq. feet — sq. inches	144	288	432	576	720	864	1008	1152	1296
Solid Measure.									
Cu. feet — cu. yards	·037037	·074074	·111111	·148148	·185185	·222222	·259259	·296296	·333333
Cu. yards — cu. feet	27	54	81	108	135	162	189	216	243
Cu. inches — cu. feet	·000579	·001158	·001737	·002316	·002895	·003474	·004053	·004632	·005211
Cu. feet — cu. inches	1728	3456	5184	6912	8640	10368	12096	13824	15552
Capacity.									
French litres — cu. feet ...	·0353156	·0706312	·1059468	·1412624	·1765780	·2118936	·2472092	·2825248	·3178404
Cu. feet — French litres .	28·3161	56·6322	84·9483	113·2644	141·5805	169·8966	198·2127	226·5288	254·8449
Gallons — cu. feet ...	·160459	·320918	·481377	·641836	·802295	·962754	1·123213	1·283672	1·444131
Cu. feet — gallons	6·23210	12·46420	18·69630	24·92840	31·16050	37·39260	43·62470	49·85680	56·08890
French litres — cu. inches ..	61·0254	122·0508	183·0762	244·1016	305·1270	366·1524	427·1778	488·2032	549·2286
Cu. inches — French litres .	·0163866	·0327732	·0491598	·0655464	·0819330	·0983196	·1147062	·1310928	·1474794
Pints — cu. inches	34·6592	69 3184	103 9776	138·6368	173·2960	207·9552	242·6144	277·2736	311·9328
Cu. inches — pints	·028848	·057696	·086544	·115392	·144240	·173088	·201936	·230784	·259632
Weight.									
Kilograms — avoir. lbs. ...	2·20462	4·40924	6·61386	8·81848	11·02310	13·22772	15·43234	17·63696	19·84158
Avoir. lbs. — kilograms ...	·453593	·907186	1·360779	1·814372	2·267965	2·721558	3·175151	3·628744	4·082337
French kilograms — tons ...	·0009842	·0019684	·0029526	·0039368	·0049210	·0059052	·0068894	·0078736	·0088578
Tons — French kilograms .	1016·05	2032·10	3048·15	4064·20	5080·25	6096·30	7112·35	8128·40	9144·45
Cu. feet of rain water — lbs. ...	62·355	124·710	187·065	249·420	311·775	374·130	436·485	498·840	561·195
Lbs.— cu. feet of rain water ...	·016037	·032074	·048111	·064148	·080185	·096222	·112259	·128296	·144333
Gallons of rain water — lbs. ...	10·0046	20·0092	30·0138	40·0184	50·0230	60·0276	70·0322	80·0368	90·0414
Lbs. — gallons of rain water ...	·099954	·199908	·299862	·399816	·499770	·599724	·699678	·799632	·899586
Cu. feet of sea water — lbs. ...	63·9762	127·9524	191·9286	255·9048	319·8810	383·8572	447·8334	511·8096	575·7858
Lbs. — cu. feet of sea water ..	·015631	·031262	·046893	·062524	·078155	·093786	·109417	·125048	·140679
Gallons of sea water — lbs. ...	10·2647	20·5294	30·7941	41·0588	51·3235	61·5882	71·8529	82·1176	92·3823
Lbs. — gallons of sea water ..	·097421	·194842	·292263	·389684	·487105	·584526	·681947	·779368	·876789
Cu. feet of sea water — tons ..	·028561	·057122	·085683	·114244	·142805	·171366	·199927	·228488	·257049
Tons — cu. feet of sea water ...	35·013	70·026	105·039	140·052	175·065	210·078	245·091	280·104	315·117
Gallons of rain water — tons...	·00447	·00894	·01341	·01788	·02235	·02682	·03129	·03576	·04023
Tons—gallons of rain water ...	223·897	447·794	671·691	895·588	1119·485	1343·382	1567·279	1791·176	2015·073
Gallons of sea water — tons ...	·004586	·009172	·013758	·018344	·022930	·027516	·032102	·036688	·041274
Tons — gallons of sea water ...	218·224	436·448	654·672	872·896	1091·120	1309·344	1527·568	1745·792	1964·016
Cubic feet of air — lbs. ...	·0755	·1510	·2265	·3020	·3775	·4530	·5285	·6040	·6795
Lbs. — cubic feet of air ...	13·2485	26·4970	39·7455	52·9940	66·2425	79·4910	92·7395	105·9880	119·2365
Cubic inches of air — lbs. ...	1·2077	2·4154	3·6231	4·8308	6·0385	7·2462	8·4539	9·6616	10·8693
Lbs.— cubic inches of air ...	·82802	1·65604	2·48406	3·31208	4·14010	4·96812	5·79614	6·62416	7·45218
Kilos. sq. cm. — lbs. sq. in. ...	14·2231	28·4462	42·6693	56·8924	71·1155	85·3386	99·5617	113·7848	128·0079
Lbs. sq. in. — kilos. sq. cm. ...	·07031	·14062	·21093	·28124	·35155	·42186	·49217	·56248	·63279

Comparison of Distances or Speeds.

Nautical Miles.	Statute Miles.	Kilometres.	Nautical Miles.	Statute Miles.	Kilometres.	Nautical Miles.	Statute Miles.	Kilometres.	Nautical Miles.	Statute Miles.	Kilometres.
1	1·152	1·853	9	10·364	16·679	17	19·576	31·504	24	27·636	44·476
2	2·303	3·706	10	11·515	18·532	18	20·727	33·357	25	28·788	46·329
3	3·455	5·560	11	12·667	20·385	19	21·879	35·210	26	29·940	48·182
4	4·606	7·413	12	13·818	22·238	20	23·030	37·064	27	31·092	50·035
5	5·758	9·266	13	14·970	24·091	21	24·182	38·917	28	32·242	51·888
6	6·909	11·119	14	16·121	25·944	22	25·333	40·770	29	33·394	53·742
7	8·061	12·972	15	17·273	27·798	23	26·485	42·623	30	34·545	55·595
8	9·212	14·825	16	18·424	29·651						

Conversion of Feet to Metres.

Ft.	Metres	Ft.	Metres	Ft.	Metres	Ft.	Metres	Ft.	Metres	Ft.	Metres	Ft.	Metres
1	·3047973	7	2·1335813	13	3·9623653	19	5·7911493	30	9·1439200	42	12·8014878	52	15·8494612
2	·6095947	8	2·4383786	14	4·2671626	20	6·0959466	32	9·7535146	44	13·4110824	54	16·4590559
3	·9143920	9	2·7431760	15	4·5719600	22	6·7055412	34	10·3631092	46	14·0206771	56	17·0686504
4	1·2191893	10	3·0479733	16	4·8767573	24	7·3511360	36	10·9727038	48	14·7022720	58	17·6782451
5	1·5239867	11	3·3527706	17	5·1815546	26	7·9247306	38	11·5822986	50	15·3118667	60	18·2878400
6	1·8287840	12	3·6755680	18	5·4863519	28	8·5343252	40	12·1918932				

Conversion of Inches to Millimetres.

In.	Millimetres	In.	Millimetres	In.	Millimetres	In.	Millimetres	In.	Millimetres	In.	Millimetres	In.	Millimetres
1	25·39977	7	177·79840	12	304·79727	17	431·79613	22	558·79499	27	685·79385	32	812·79271
2	50·79954	8	203·19818	13	330·19704	18	457·19590	23	584·19476	28	711·19362	33	838·19248
3	76·19932	9	228·59795	14	355·59681	19	482·59567	24	609·59453	29	736·59339	34	863·59225
4	101·59909	10	253·99772	15	380·99658	20	507·99544	25	634·99430	30	761·99316	35	888·99202
5	126·99886	11	279·39749	16	406·39635	21	533·39521	26	660·39408	31	787·39294	36	914·39180
6	152·39863												

Sixty-fourths of an Inch in Millimetres.

Sixty-fourths	Millimetres	Sixty-fourths	Millimetres	Sixty-fourths	Millimetres	Sixty-fourths	Millimetres	Sixty-fourths	Millimetres	Sixty-fourths	Millimetres	Sixty-fourths	Millimetres
1	·396871	11	4·365586	20	7·937429	29	11·509272	38	15·081115	47	18·652958	56	22·224801
2	·793743	12	4·762457	21	8·334300	30	11·906143	39	15·477986	48	19·049829	57	22·621672
3	1·190614	13	5·159329	22	8·731172	31	12·303015	40	15·874858	49	19·446701	58	23·018543
4	1·587486	14	5·556200	23	9·128043	32	12·699886	41	16·271729	50	19·843572	59	23·415415
5	1·984357	15	5·953072	24	9·524915	33	13·096757	42	16·668600	51	20·240443	60	23·812286
6	2·385129	16	6·349943	25	9·921786	34	13·493629	43	17·065472	52	20·637315	61	24·209158
7	2·778100	17	6·746814	26	10·318657	35	13·890500	44	17·462343	53	21·034186	62	24·606029
8	3·174972	18	7·143686	27	10·715529	36	14·287372	45	17·859215	54	21·431058	63	25·002901
9	3·571843	19	7·540557	28	11·112400	37	14·684243	46	18·256086	55	21·827929	64	25·399772
10	3·968714												

Inches and Fractions in Millimetres.

In.	0	1	2	3	4	5	6	7	8	9	10	11	In.
	—	25·400	50·799	76·199	101·60	127·00	152·40	177·80	203·20	228·60	254·00	279·39	
1/16	1·5875	26·987	52·387	77·786	103·19	128·59	153·98	179·38	204·78	230·18	255·58	280·98	1/16
1/8	3·1749	28·574	53·974	79·374	104·77	130·17	155·57	180·97	206·37	231·77	257·17	282·57	1/8
3/16	4·7624	30·162	55·561	80·961	106·36	131·76	157·16	182·56	207·96	233·36	258·76	284·16	3/16
1/4	6·3499	31·749	57·149	82·549	107·95	133·35	158·75	184·15	209·55	234·95	260·35	285·74	1/4
5/16	7·9374	33·337	58·736	84·136	109·54	134·94	160·33	185·73	211·13	236·53	261·93	287·33	5/16
3/8	9·5248	34·924	60·324	85·723	111·12	136·52	161·92	187·32	212·72	238·12	263·52	288·92	3/8
7/16	11·112	36·512	61·911	87·311	112·71	138·11	163·51	188·91	214·31	239·71	265·11	290·51	7/16
1/2	12·700	38·099	63·499	88·898	114·30	139·70	165·10	190·50	215·90	241·30	266·70	292·09	1/2
9/16	14·287	39·687	65·086	90·486	115·89	141·28	166·68	192·08	217·48	242·88	268·28	293·68	9/16
5/8	15·875	41·274	66·674	92·073	117·47	142·87	168·27	193·67	219·07	244·47	269·87	295·27	5/8
11/16	17·462	42·862	68·261	93·661	119·06	144·46	169·86	195·26	220·66	246·06	271·46	296·86	11/16
3/4	19·050	44·449	69·849	95·248	120·65	146·05	171·45	196·85	222·25	247·65	273·05	298·44	3/4
13/16	20·637	46·037	71·436	96·836	122·24	147·63	173·03	198·43	223·83	249·23	274·63	300·03	13/16
7/8	22·225	47·624	73·024	98·423	123·82	149·22	174·62	200·02	225·42	250·82	276·22	301·62	7/8
15/16	23·812	49·212	74·611	100·01	125·41	150·81	176·21	201·61	227·01	252·41	277·81	303·21	15/16

Decimal Equivalents of Fractions (as of an Inch).

1/64	1/32	3/64	1/16	5/64	3/32	7/64	1/8	9/64	5/32	11/64	3/16	13/64	7/32	15/64	1/4
·01562	·03125	·04687	·0625	·07812	·09375	·10937	·125	·14062	·15625	·17187	·1875	·20312	·21875	·23437	·25
17/64	9/32	19/64	5/16	21/64	11/32	23/64	3/8	25/64	13/32	27/64	7/16	29/64	15/32	31/64	1/2
·26562	·28125	·29687	·3125	·32812	·34375	·35937	·375	·39062	·40625	·42187	·4375	·45312	·46875	·48437	·5
33/64	17/32	35/64	9/16	37/64	19/32	39/64	5/8	41/64	21/32	43/64	11/16	45/64	23/32	47/64	3/4
·51562	·53125	·54687	·5625	·57812	·59375	·60937	·625	·64062	·65625	·67187	·6875	·70312	·71875	·73437	·75
49/64	25/32	51/64	13/16	53/64	27/32	55/64	7/8	57/64	29/32	59/64	15/16	61/64	31/32	63/64	
·76562	·78125	·79687	·8125	·82812	·84375	·85937	·875	·89062	·90625	·92187	·9375	·95312	·96875	·98437	

Birmingham or English Standard Gauge.

Number ...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Decimal In. ...	·300	·284	·259	·238	·220	·203	·180	·165	·148	·134	·120	·109	·095	·083	·072
Nearest Fraction } In. ...			1/4 17/64			13/64	3/16	5/32			1/8	7/64	3/32	5/64	

Number ...	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Decimal In. ...	·065	·058	·049	·042	·035	·032	·028	·025	·022	·020	·018	·016	·014	·013	·012
Nearest Fraction } In. ...	1/16		3/64			1/32						1/64			

Specific Gravity and Weight of Materials.

METALS. Name.	Specific Gravity.	Lbs. in a Cubic Foot.	METALS. Name.	Specific Gravity.	Lbs. in a Cubic Foot.	TIMBER. Name.	Specific Gravity.	Lbs. in a Cubic Foot.
Aluminium, cast	2·560	160·0	Lead, sheet	11·400	712·8	Fir, yellow pine	·461	28·8
,, sheet	2·670	166·9	Steel, cast	7·829	489·3	,, larch	·496	31·0
Brass, cast	8·396	524·8	,, hard	7·818	488·6	Lignum-vitæ	1·333	83·2
,, sheet	8·525	532 8	,, soft	7·834	489·6	Mahogany, Honduras	·560	35·0
,, wire	8·544	533·0				,, Spanish	·853	53·2
Bronze	8·222	513·4	TIMBER.			,, Australian	·952	59·4
Copper, cast	8·607	537·9				Oak, British	·934	58·3
,, sheet	8·785	549 1	Ash	·753	47·0	,, Riga	·688	43·0
,, wire	8·878	548·6	Cedar	·486	30·8	,, Dantzic	·756	47·2
Gun metal	8·153	509·6	Elm	·544	33·8	,, red	·872	54·4
Iron, cast, average	7 125	445·3	Fir, red pine	·577	36 1	Teak, Indian	·880	55·0
,, wrought, average	7·680	480·0	,, pitch pine	·660	41·2	,, African	·983	61·3
Lead, cast	11·352	709 5	,, spruce	·512	32·0	Walnut	·671	41·8

Approximate Weight of Copper Pipes per Foot of Length.

Thickness.	Internal Diameter (Inches).											
Inch.	1/4	1/2	3/4	1	1¼	1½	1¾	2	2¼	2½	2¾	3
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1/16	·23	·42	·61	·80	·99	1·18	1·37	1·56	1·75	1·94	2·13	2·31
1/8	·56	·94	1·32	1·70	2·08	2·46	2·84	3·22	3·59	3·97	4·35	4·73
3/16	·99	1·56	2·13	2·69	3·26	3·83	4·40	4·96	5·53	6·10	6·67	7·24
1/4	1·51	2·27	3·02	3·78	4·54	5·29	6·05	6·81	7·56	8·32	9·08	9·74

Weight per Square Foot of Metal Plates.

Thickness (in.)	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Wrought Iron ...	2·5	5·0	7·5	10·0	12·5	15·0	17·5	20·0
Cast Iron	2·34	4·69	7·03	9·38	11·7	14·1	16·4	18·7
Steel...	2·55	5·10	7·65	10·2	12·8	15·3	17·9	20·4
Copper	2·89	5·79	8·68	11·6	14·5	17·4	20·3	23·2
Brass	2·63	5·26	7·89	10·5	13·2	15·8	18·4	21·1

Working Strength (in cwts.) and Weight (in lbs. per fathom) of Ropes.

Circumference, Inches.	Common Hemp.		Good Hemp.		Steel Wire.	
	Str'ngth.	Weight.	Str'ngth.	Weight.	Str'ngth.	Weight.
1	·64	·18	·92	·24	9·0	·89
$1\frac{1}{4}$	1·00	·28	1·44	·38	14 0	1·39
$1\frac{1}{2}$	1·44	·41	2·08	·54	20·2	2·00
$1\frac{3}{4}$	1·96	·55	2·82	·74	27·6	2·73
2	2·56	·72	3·68	·96	36 0	3·56
$2\frac{1}{4}$	3·24	·91	4·66	1·22	45·6	4·51
$2\frac{1}{2}$	4·00	1·13	5·76	1·50	56·2	5·56
$2\frac{3}{4}$	4·84	1·36	6·96	1·82	68·0	6·73
3	5·76	1·62	8·28	2·16	81·0	8·01

Tonnage Measurement.

All vessels over a certain size are rated by some method of tonnage measurement, different systems being employed for various purposes by the several persons and authorities concerned.

Register Tonnage.—This is used by the Customs House and by the Board of Trade, and represents approximately the entire internal cubical capacity of a vessel in tons of 100 cubic feet.

Register Tonnage $= \frac{L \times B \times D}{100} \times C.$

where L = inside length on deck from plank at stem to plank at stern.
B = inside breadth at ceiling.
D = inside 'midship depth.
C = ·45 for yachts under 60 tons.
= ·5 „ over „

Gross Tonnage includes the whole internal capacity of the vessel.

Net Tonnage is the gross tonnage less the crew and engine space, etc.

Dead Weight Capacity is the actual carrying capacity to bring the vessel down to the Plimsoll mark.

Displacement Tonnage is the actual total weight of the vessel with cargo, etc., aboard.

Yacht Measurement or Thames Tonnage.—This is the method usually in vogue for the measurement of yachts. All fractional parts of a ton are reckoned as a full ton.

$$T = \frac{(L-B) \times B \times \frac{1}{2}B}{94}$$

L is measured from the fore side of stem to the after side of stern post on deck.

Builders' Measurements.—This is a method employed by builders, but is not otherwise in very general use.

$$T = \frac{(L-\frac{3}{5}B) \times B \times \frac{1}{2}B}{94}$$

where L = length along rabbet of keel from back of main stern post to a perpendicular from the forepart of main stem under the bowsprit.
B = greatest beam to outside of planking, excluding doubling planks.

On the Bow River in the Rocky Mountains. Three motor launches are on hire just above the point illustrated, which is over 5,400 feet above sea level.

GLOSSARY OF TERMS USED IN MARINE MOTORING.

For terms used in this book and not given here refer to the Index.

A

A.—The class of the excellence of sea-going merchant ships on Lloyd's books, subdivided into 100 A., 90 A., etc., 100 A. being the highest class. The difference is chiefly due to thickness of plating, or to age. A small letter inside the A. indicates a finer classification of each section in accordance with certain rules laid down. Coasting vessels and special service vessels are classed under different characters.

ABACK.—A vessel is taken aback when the wind strikes the sails in such manner as to tend to drive her astern. If driven astern she is said to make a "stern board."

ABAFT.—This word, generally speaking, means behind, inferred relatively, beginning from the stem and continuing towards the stern, that is, the hinder part of the ship. Abaft the beam implies any direction between a supposed transverse line amidships and the stern, whether in or out of the ship. It is the relative situation of an object with the ship, when that object is placed in the arc of the horizon contained between a line at right angles with the keel and the point of the compass, which is directly opposite the ship's course. An object—as a man overboard—is described by the look-out man at the masthead as abeam, before, or abaft the beam, by so many points of the compass; or as a vessel seen may be "three points before the beam," etc.

ABEAM.—In a line at right angles to the vessel's length; opposite the centre of the ship's side.

ABOARD.—On board a vessel.

Close aboard.—Close alongside.

ABREAST.—Side by side, parallel, or opposite to; generally used in opposition to abaft or afore. Abreast of a place is directly off it, a direction at right angles with the keel or ship's length.

ACCUMULATOR.—See Index.

ADIABATIC (expansion or contraction of a gas).—Change of volume without any transference of *heat* taking place. Thus a gas expanding adiabatically will fall in *temperature.* Also known as isentropic expansion.

ADMIRALTY MILE.—A distance of 6,080ft. measured and marked by the Admiralty for the purpose of speed trials.

ADRIFT.—Floating at random; the state of a boat or vessel broken from her moorings, and driven to and fro without control by the winds and waves. Cast loose, cut adrift.

AFLOAT.—Borne up and supported by the water; buoyed clear of the ground; also used for being on board ship.

AFT.—Contradistinctive of fore, and an abbreviation of abaft—the hinder part of the ship, or that nearest the stern. Right aft is in a direct line with the keel from the stern. To haul aft a sheet is to pull on the rope which brings the clew, or corner of the sails more in the direction of the stern. The mast rakes aft when it inclines towards the stern.

AHEAD.—A term especially referable to any object farther onward, or immediately before the ship, or in the course steered, and therefore opposed to astern. Ahead of the reckoning is sailing beyond the estimated position of the ship.

A-LEE.—The contrary of a-weather; the position of the helm when its tiller is borne over to the lee-side of the ship, in order to go about or put her head to windward. "Hard a-lee!" or "luff a-lee!" an order to the steersman to put the helm down. "Helm's a-lee!" the word of command given on putting the helm down, and causing the head-sails to shake in the wind.

ALOFT.—Above, overhead, on high. Synonymous with up above the tops, at the masthead, or anywhere about the higher yards, masts, and rigging of ships. "Aloft there!" the hailing of people in the tops. "Away aloft!" the command to the people in the rigging to climb to their stations.

AMIDSHIPS.—The middle of the ship, whether in regard to her length between stem and stern, or in breadth between the two sides. To put the helm amidships is to place it in a line with the keel.

AMMETER.—Same as "Ampéremeter."

AMPERE.—See Index.

AMPEREMETER.—An instrument for measuring the strength of an electrical current in ampéres.

ANNULAR —In the form of a ring.

ANODE (in a primary battery).—The negative electrode. In any cell containing an electrolyte through which a current is passing, the electrode by which the current enters the cell.

ANTHRACITE.—A special kind of hard Welsh coal.

ANTI-FOULING COMPOSITION.—Composition in the form of paint, which is applied to the under-water portion of a vessel to prevent it accumulating a growth of weeds, etc.

ARC.—A gap in an electric circuit, across which current is passing, owing to the presence of fused particles in the gap, the voltage of the circuit not being sufficient to cause a spark to jump the gap. An arc can therefore only be formed by putting two conductors in contact and then separating them. A spark as from an induction coil is not an arc.

ARCHBOARD.—The curved frame which takes the after ends of the planking in a vessel's counter.

AREA OF PROPELLER.—The sum of the actual areas of the blades.

Disc area.—The area of a circle of same radius as propeller blade. Blade area rarely exceeds .6 of the disc area.

ARMATURE (of a coil).—That portion of the trembler which is attracted by the magnetised core of

the coil. In a magneto the iron core and the coil or coils wound on it.

ASTERN.—Any distance behind a vessel; in the after-part of the ship; in the direction of the stern, and therefore the opposite of "ahead." To drop astern is to be left behind; when abaft a right angle to the keel amidships a boat drops astern.

ATHWART.—The transverse direction; anything extending across the line of a ship's course. "Athwart hawse," a vessel, boat, or floating lumber accidently drifted across the stem of a ship, the transverse position of the drift being understood. "Athwart the forefoot," just before the stem. "Athwart ships," in the direction of the beam; from side to side; in opposition to "fore and aft."

ATOMISED (fuel).—Fuel reduced to a very finely divided state, really minute globules of liquid; atomised fuel is not, however, true gas.

A-TRIP.—The anchor is a-trip, or a-weigh, when the purchase has just made it break ground, or raised it clear. Sails are a-trip when they are hoisted from the cap, sheeted home, and ready for trimming.

ATTENUATED (gas).—Gas or vapour under a pressure less than that of the atmosphere.

AUTOMATIC VALVE.—One which opens or closes by variation of pressure on its face without other operating mechanism beyond a spring.

AVAST.—The order to stop, hold, cease, or stay in any operation.

AVAST HEAVING.—The cry to arrest the capstan or winch when nippers are jammed, or any other impediment occurs when heaving in the cable or rope.

A-WEATHER.—The position of the helm when its tiller is moved to the windward side of the ship, in the direction from which the wind blows. The opposite of "A-lee."

A-WEIGH.—The anchor being a-trip, or after breaking out of the ground.

AY, AY, SIR.—A prompt reply on receiving an order. Also the answer on comprehending the order. (Pronounced, eye, eye.)

B

BACK.—To "back an anchor" is to carry a small anchor ahead of the one by which the ship rides, to partake of the strain, and check the latter from coming home. To "back and fill," is to get to windward in very narrow channels, by a series of smart alternate boards and backing, with weather tides. To "back a sail," is to brace its yard, so that the wind may blow directly on the front of the sail, and thus retard the ship's course. A sailing vessel is "backed" by means of the sails, a steamer by reversing the paddles or screw-propeller. To "back astern"; to impel the water with the oars contrary to the usual mode, or towards the head of the boat, so that she shall recede. To "back a rope or chain," is to put on a preventer when it is thought likely to break from age or extra strain. To "back water"; to impel a boat astern, so as to recede in a direction opposite to the former course.

BACK-FIRE.—An explosion taking place in an engine in the compression stroke, so that the direction of running of the engine is reversed.

BACK STAY.—See Index, *Masts and Sails, Names of.*

BAFFLING.—A term applied to the wind when it frequently shifts from one point to another.

BALLAST.—A certain portion of stone, pig-iron, gravel, water, or such like materials, deposited in a ship's hold when she either has no cargo or too little to bring her sufficiently low in the water.

BARE POLES.—The condition of a ship having no sails set when out at sea, and either scudding, or lying-to, by stress of weather.

BATTENS.—In general, pieces of wood from 1in. to 3in. broad. Long slips of fir used for setting fair the sheer-lines of a ship, drawing the lines by in the moulding loft, or setting off distances. Also, thin strips of wood put upon rigging, to keep it from chafing, by those who dislike mats; when large these are designated "Scotchmen."

BATTENS OF THE HATCHES.—Long narrow laths of wood or iron, serving by the help of wedges to confine the edges of the tarpaulins, and keep them close down to the sides of the hatchways, in bad weather.

BEACON.—A post or stake erected over a shoal or sandbank, as a warning to seamen to keep at a distance; also a signal mark placed on the top of hills, eminences, or buildings near the shore for the safe guidance of shipping.

BEAM.—The greatest width of a vessel.

BEAM-ENDS.—A ship is said to be on her beam-ends when she has heeled over so much on one side that her beams approach to a vertical position.

BEARER ARMS.—Extensions or arms of the crank-case of an engine used to support it on its bearers.

BEARERS (engine).—Bearers or iron girders in a vessel to which the engine is bolted.

BEARING.—(1) (of mechanism).—The support in or on which a part of the mechanism moves.

(2).—The direction (by compass or otherwise) in which an object lies referred to the position of the observer or of the vessel.

(3) *Bearing up or away.*—Altering course away from wind.

BEATING, OR TURNING TO WINDWARD.—The operation of making progress by alternate tacks at sea against the wind, in a zig-zag line, or transverse courses; "beating," however, is generally understood to be turning to windward in a storm or fresh wind.

BEAU DE ROCHAS CYCLE.—See Index.

BECALM, TO.—To intercept the current of the wind in its passage to a ship, by means of any contiguous object, as a high shore, some other ship to windward, etc. At this time the sails remain in a sort of rest, and are consequently deprived of their power to govern the motion of the ship. Thus one sail becalms another. Also called "blanketing."

BEFORE OR ABAFT THE BEAM.—The bearing of any object which is before or abaft a line at a right angle to the keel, at the midship section of a ship.

BELL CRANK.—A contrivance working about a pivot, and consisting of two arms rigidly connected together at an angle, by means of the extremities of which reciprocating motion may be transmitted in a diverted direction, as in the case of the common corner quadrants of old-fashioned wire-pull house bells.

BELLY.—The swell of a sail. To belly a sail is

to inflate or fill it with the wind, so as to give it a taut leech.

Bend, To.—To fasten one rope to another, or to an anchor, etc.

B.H.P.—Brake horse-power. (See Index.)

Big End (of a connecting rod).—The end of the rod attached to the crank pin of the engine shaft.

Bight.—The loop of a rope when it is folded; in contradistinction to its ends.

Bilge, or Bulge.—That part of the floor in a ship—on either side of the keel—which approaches nearer to a horizontal than to a perpendicular direction, and begins to round upwards.

Bilge Keels are keels bolted on to the bilge of many vessels to make them easier in a seaway by preventing excessive rolling.

Binnacle.—The stand or case carrying the steering compass.

Binnacle Light.—The oil or electric lamp which illuminates the compass card in the binnacle.

Bischoff Cycle.—See Index.

Bitts.—A frame composed of two strong pieces of straight oak timber, fixed upright in a ship, and bolted securely to the beams, whereon to fasten the cables or other ropes; also iron or steel cylindrical castings bolted in places about the decks.

Block and Block.—The situation of a tackle when the blocks are drawn close together.

Bluff (bow).—Blunt, like the bow of a barge.

Board.—The space comprehended between any two places when the ship changes her course by tacking; or, it is the line over which she runs between tack and tack when working to windward, or sailing against the direction of the wind. To make a "good board." To sail in a straight line when close-hauled without deviating to leeward. To make "short boards," is to tack frequently before the ship has run any great length of way. To make a "stern board," is when by a current, or any other accident, the vessel comes head to wind, the helm is shifted, and she has fallen back on the opposite tack, losing what she had gained, instead of having advanced beyond it. (See "Aback.") The word board has various other applications among seamen. To "go aboard" signifies to go into the ship. To "slip by the board" is to slip down a ship's side. To "board it up," is to beat up, sometimes on one tack, and sometimes on another. The "weather-board" is the side of the ship which is to windward. "By the board," means close to a ship's deck.

Boat-chocks.—Clamps of wood upon which a boat rests when stowed on a vessel's deck.

Boatswain.—The officer who superintends the boat sails, ship sails, rigging, canvas, colours, anchors, cables, and cordage, committed to his charge. Although termed boatswain, the boats are not in his charge. They, with the spars, etc., and stores for repair, belong to the carpenter.

Boat the Oars.—Put them in their proper places fore and aft on the thwarts ready for use.

Bobstay.—See Index, *Masts and Sails, Names of.*

Bobstay Plates.—Iron plates by which the lower end of the bobstay is attached to the stem.

Body Plan.—The drawing of a proposed ship, showing the breadth and timbers; it represents a section through the broadest part of the vessel; it is otherwise called the plan of projection.

Bollard.—A single post or a pair of strong, stumpy, wood or iron posts, generally when of iron with enlarged tops, for turning ropes round and so securing them.

Bolsters.—Small cushions or bags of tarred canvas used to preserve the stays from being chafed by the motion of the masts, when the ship pitches at sea. Pieces of soft wood covered with canvas, placed on the trestle-trees, for the eyes of the rigging to rest upon, and to prevent a sharp nip.

Booby-hatch.—A smaller kind of companion, but readily removable; it is in use for half-decks, and lifts off in one piece.

Boom.—A long spar run out from different places in the ship, to extend or boom out the foot of a particular sail; as, jib-boom, flying jib-boom, studding-sail booms, driver or spanker boom, main boom, square-sail boom, etc. Boom also denotes a cable stretched athwart the mouth of a river or harbour with yards, topmasts, or stout spars of wood lashed to it, to prevent the entrance of an enemy. To "top one's boom," is to start off. To "boom off," is to shove a boat or vessel away with spars.

Bore.—A sudden and rapid flow of tide in certain inlets of the sea.

Bout.—"'Bout ship," the brief order for "about ship."

Bow (pronounced similar to cow).—Either side of a vessel just abaft the stem. (See also "Bows.")

On the (port or starboard) bow.—In a direction varying from not quite right ahead to not quite at right angles to the vessel.

Bower Anchors.—The anchors at the bows and in constant working use.

Bows (pronounced similar to cows).—All the extreme forward part of the hull of a vessel.

Bowse, To.—To pull upon any body with a tackle to haul it taut.

Bowsprit (pronounced bo-sprit).—The more or less horizontal spar protruding from the front of a vessel to which the mast is stayed.

Box the Compass, To.—Signifies the ability to repeat the names of the 32 points in order both forwards and backwards, as also to answer any and all questions respecting the divisions of the compass-card.

Braces.—See Index, *Masts and Sails, Names of.*

Brazed.—Joined by a fusible alloy of yellow metal.

Breasthook.—A crooked knee of wood or steel serving to strengthen the connection between the stem and the upper portion of the boat's sides.

Bring-to, To.—To check the course of a ship by trimming the sails so that they shall counteract each other and keep her nearly stationary; she is then said to lie by, or lie-to, or heave-to "Bring to an anchor." The act of anchoring a vessel.

Broach-to, To.—To fly up into the wind. It generally happens when a ship is carrying a press of canvas with the wind on the quarter, and a good deal of after-sail set. In extreme cases the sails are caught flat aback; in such case the masts are likely to give way.

Brush.—An electrical conductor used to collect current from a rotating conductor.

Bulkhead.—A transverse partition dividing the interior of a hull into sections.

Bull Rope.—A rope rove through a block in the bowsprit and bent to a buoy the ship is moored

to keep the buoy clear of the stem. A rope used to clear a foul anchor.

BULL'S-EYE.—A more or less spherical block of metal or hard wood (generally lignum vitæ) with a groove round it to enable it to be held in an eye splice or otherwise at the end of a rope, and with a hole through it acting as a fair-lead for another rope.

BUNT.—The middle part of a square sail.

BUOY.—A sort of close cask, or block of wood, fastened by a rope to the anchor, to show its position. Buoys of various kinds are also placed upon rocks or sand-banks to direct mariners where to avoid danger.

BUREAU VERITAS.—The French equivalent of Lloyd's.

BURRS.—See "Roves."

BUS BAR.—An electrical conductor, to which all the current from the source of supply is fed, and from which a number of branch circuits are supplied.

BUSH.—A cylindrical bearing in one piece.

BUTT.—A straight joint in planking at right angles to the length of the planks. The joining of two timbers or planks endways. In iron ships the end of the skin plates.

BY.—On or close to the wind. "Full and by," not to lift or shiver the sails

BY THE BOARD.—Over the ship's side. When a mast is carried away near the deck it is said to "go by the board."

BY THE HEAD.—When a ship is deeper forward than aft.

BY THE STERN.—When the ship draws more water aft than forward. (See "By the Head.")

C

CABLE (1).—A measure of distance at sea: one-tenth of a nautical mile, 608ft., but more usually taken as 200yds.

(2).—The chain, wire, or rope attached to the anchor for anchoring or mooring the vessel.

CALIBRE.—The internal diameter of a pipe or tube.

CALL, OR PIPE.—A peculiar silver pipe or whistle, used by the boatswain and his mates.

CALLIPERS.—Compasses with inwardly or outwardly curved points used in workshops for measuring diameters of shafts, cylinders or bearings, etc.

CAMBER.—The round upon the upper deck; the curve of a ship's plank; a small tidal basin.

CANT, TO.—To turn anything about, so that it does not stand square.

CAPACITY (Electrical).—Strictly speaking, a measure of the capability of a condenser to absorb electricity. A condenser of unit capacity (one Farrad) would have a potential of one volt produced between its two sets of plates, if supplied with one coulomb of electricity. Of accumulators, capacity is taken as a product of the strength of current and of the time for which it can be maintained. Thus a cell of 10 ampere-hours capacity could supply a current of 1 ampere for 10 hours, or a current of 10 amperes for one hour.

CAPPING, OR RAIL.—The moulding on top of the bulwark or gunwale of a vessel.

CAPSTAN.—A mechanical arrangement for lifting great weights, usually the anchors.

CAPSTAN BARS.—Long pieces of wood of the best ash or hickory, one end of which is thrust into the square holes in the drum head, like the spokes of a wheel. They are used to heave the capstan round, by the men setting their hands and chests against them and walking round.

CARBURATION.—The process of mixing atomised fuel with air. The fuel being chemically a hydrocarbon is said to carburate (or carburet) the air.

CAREENING.—The operation of heaving the ship down on one side.

CARLINES.—Fore and aft framing round hatchways or other openings in a deck.

CASE-HARDENED IRON.—Iron with an outer skin of extreme hardness. (See "Steel, Chrome.")

CAST OF THE LEAD.—The act of heaving the lead into the sea to ascertain what depth of water there is.

CAT'S-PAW.—A light air perceived at a distance in a calm by the impressions made on the surface of the sea, which it sweeps very gently, and then passes away, being equally partial and transitory.

CAULKING.—Forcing a quantity of oakum, or old ropes untwisted and drawn asunder, into the seams of the planks.

CAVITATION.—The partial vacuum formed behind a propeller blade when revolving at too high a speed.

CENTRIFUGAL.—Outwards from a centre.

CENTRIPETAL.—Inwards towards a centre.

CHARGING (Accumulators).—The act of sending a current through the cells. See Index.

CHART.—A sea map showing depths of water, coast lines, beacons, lights, buoys, currents, etc.

CHARTER.—To charter a vessel is to hire her for a time or for a voyage.

CHECK.—To slack off a rope a little, and belay it again.

CHIME, OR CHINE.—A longitudinal frame connecting the sides and bottom of a barge or other vessel having a sharp angle at their junction.

CHOCK.—A block or wedge of wood or other material used to prevent motion, or as a support. A block to prevent the cradle or frame on which a vessel is built from slipping on the ways.

CHOKE THE LUFF.—To place suddenly the fall of a tackle close to the block across the jaw of the next turn of the rope in the block, so as to prevent the leading part from rendering.

CLEAT (1).—Shaped piece of wood or metal round which a rope may be secured.

(2).—Any small piece of wood to prevent movement of other pieces.

CLENCH, OR CLINKER.—That method of boat construction in which the edges of the planks overlap.

CLENCHING.—Turning over the end of a nail.

CLEW.—The after lower corner of a fore-and-aft sail or the two lower corners of square sails. See also Index, *Masts and Sails, Names of.*

CLOSE-HAULED.—The general arrangement or trim of a ship's sails when she endeavours to progress in the nearest direction possible contrary to the wind.

CLOSE-REEFED.—When under lower tops'ls and fores'l, or, in small craft, when the sails are made as small as possible by reefing.

CLUTCH.—A device for connecting at will a driving and a driven shaft.

COACH SCREW.—A large screw for wood with long shank and square or hexagonal head.

COAMINGS (of the Hatches or Gratings).—Certain

raised work about the edges of the hatch-openings of a ship to prevent the water on deck from running down.

COCK BILL.—The situation of the anchor when suspended from the cat-head ready for letting go.

COMMUTATOR (in motor work).—A device for interrupting a low-tension circuit. This word is a misnomer, for in electrical engineering a commutator is an arrangement for passing current from the armature to the brushes of a dynamo, or vice versa.

COMPANION.—A hatchway with a house or large fixed hatch over it to admit of entrance.

CONDENSER, ELECTRICAL.—See Index.

CORE.—A shape of sand used in casting.

CORE PRINT.—Projections from a core used to keep it in position in its mould.

COTTER.—A piece of metal, generally flat, sometimes wedge shaped and sometimes with up-turned ends, used to jam a bearing in position, to hold a cutting tool in a boring bar, or to hold a spring-backed washer on a spindle.

COULOMB.—The electrical unit of quantity, equal to a current of one ampere flowing for one second. The equivalent in hydrostatics of so many cubic feet of water.

COUNTER (1).—An instrument with a graduated scale, used for counting the revolutions of the engine or other shaft.

(2).—The overhanging part of the stern of a vessel clear of the water-line and beyond the stern-post.

COUNTER-SUNK.—Those holes which are made for the heads of bolts, rivets or nails to be sunk in, so as to be even with the general surface.

COUPLE.—Two equal and parallel but opposite forces acting through points in a rigid body some distance apart and tending to turn it.

COURSE (of a ship).—(1) The direction on the chart, or by compass, in which it is proceeding

(2).—(A sail), the lowest square sail on mast of a square-rigged vessel.

COVERING BOARD.—The outer plank of the deck, which is shaped to the outline of the vessel, and, in conjunction with the shelf, connects the deck and sides.

CRADLE.—The framework upon which a vessel is launched or hauled out of water.

CRAMP.—A mechanical contrivance for drawing two pieces of wood or other objects together; usually actuated by a screw.

CRANK, OR CRANK-SIDED, is applied to a vessel which, by her construction or her stowage, is inclined to lean over a great deal; or which, from insufficient ballast or cargo, is incapable of carrying sail, without danger of overturning. The opposite term is "stiff," or the quality of standing well up to her canvas.

CRANKSHAFT conveys the power from the connecting rod to the propeller-shaft.

CROSS-JACK (pronounced cro'jack).—See Index, *Masts and Sails, Names of.*

CROSS SPAULS.—Cross ties, temporarily fixed from side to side of a vessel to keep her in shape until the deck beams are in.

CROW-FOOT.—A number of small lines spreading out from an arrow or long block, used to suspend the awnings by.

CRUDE OIL.—Unrefined oil obtained direct from the oil springs.

CUT-OFF.—The point, in relation to the stroke, at which the steam or fuel supply is cut off.

CYCLE (of internal combustion engine).—The series of operations performed on the gases in the cylinder.

CYCLE, BEAU DE ROCHAS.—See Index.

CYCLE, OTTO, BISCHOFF.—See Index.

D

DAVIT.—A piece of timber or iron with sheaves or blocks at its end, projecting over a vessel's side to hoist up and suspend one end of a boat or anchor.

DEAD RECKONING.—Distance covered by a vessel as calculated by the log, making allowance for tides, etc., without observations of sun or stars, or of fixed marks or beacons.

DEAD WATER.—The eddy-water under the counter of a ship under way; it is so called because it passes away slower than the water alongside.

DEADWOOD (1).—A heavy piece of timber, more or less in the form of a knee, connecting the stem or stern post of wooden vessels with the keel, part of which may be outside the planking.

(2).—The lower part of the stem or stern of a vessel with considerable hollow in her sections at these points.

DECOMPOSITION (of Fuels).—The breaking up of a fuel into its component parts under the influence of heat, but without burning.

DENSIMETER —An instrument (usually a glass tube containing some coloured discs of suitable weight) which registers the density of any liquid in which it is immersed, relatively to the density of water. The density of water in these instruments is usually taken as 1,000, so that petrol with a density equal to decimal 7 that of water would give a densimeter reading of 700. Similarly, sulphuric acid of a strength suitable for accumulators would read 1,200, that is, 1.2 times as heavy as water.

DEPOLARISER.—Any chemical used to prevent polarisation

DERELICT.—An abandoned vessel.

DIE.—A hard metal form in which soft metal is pressed or worked to take a shape as determined by the form used.

DIFFERENTIAL (Gear) (in a boat).—A combination of gear wheels for causing the propeller shaft to revolve in the reverse direction to the engine shaft (In a road vehicle).—To permit one of two driven wheels on the same line of axle to revolve quicker than the other, as when turning a corner The bevel wheel type of differential consists of a bevel spur wheel driving another bevel spur wheel on the same *line* of shaft by means of small intermediate bevel pinions.

DIOPTRIC.—A form of lens with horizontal angular rings for the better diffusion of light in ships' lamps. Another form is known as "lenticular." In this case the whole surface of the glass is cut in facets, each of which reflects the light and greatly increases the power of the lamp.

DISC AREA.—See "Area."

DISTRIBUTOR (High-tension).—See Index.

DITTY BAG.—It is in use among seamen for holding their necessaries.

DOCK DUES.—The charges made upon shipping for the use of docks.

DRAUGHT, OR DRAFT.—The depth of water a ship displaces, or of a body of fluid necessary to float a vessel, hence a ship is said to draw so many

feet of water when she requires that depth to float her; this is, for convenience, marked on the stem and stern-post from the keel upwards, in figures which are usually 6in. long and 6in. apart, the bottom of the figures representing the depth.

DRAWBACK.—An allowance by the Government under which duties paid are returnable wholly or in part.

DROGUE.—A spar or sea anchor used to lay a boat to at sea, or to prevent her being driven in on a beach too quickly, by hanging it over the stern to a line.

DROP FORGING.—A shaped piece of metal (iron or steel) forged between dies under the action of a falling heavy weight.

DROWNED (of a pump).—Filled with water (or other liquid) when at rest, or which will fill at once on being started, without the necessity for any suction action, owing to the free surface of the liquid being at a higher level than the pump.

DUCT.—A small tube or similar passage

E

EARTH (Connection).—A very loosely-applied term indicating a connection to any part of the frame of an engine

EFFICIENCY, MECHANICAL.—The ratio of the power actually available to that theoretically attainable.

EFFICIENCY, THERMAL.—The ratio of the energy imparted to a piston by an explosion in its cylinder to the theoretical heat value of the fuel.

ELECTRODE —Plates or other shapes immersed in an electrolyte, and used to conduct the current to or from the liquid.

ELECTROLYSIS —The decomposing action of an electric current on an electrolyte.

ELECTROLYTE.—A liquid through which an electric current passes and which is decomposed by that current

ELECTRO MAGNET —One or more pieces of iron temporarily magnetised by an electric current, the magnetism disappearing as soon as the current ceases.

ENTRANCE.—A term for the bow of a vessel. That part of the fore part of the ship from the cutwater to the part it swells out to the full beam of the ship.

EPICYCLIC GEAR.—A system of toothed wheels for obtaining a reduction of speed of revolution or a reverse drive. (Only the latter type will be found in a boat.) A central driving spur wheel meshes with small pinions round its circumference, which, in turn, mesh with an internally-toothed ring wheel. (See Index.)

F

FAIR-LEAD.—A contrivance through which a rope is led to clear an obstruction and to avoid chafing.

FALL.—The free end of the rope of a halyard, sheet, or purchase.

FALLS.—The purchases used for hoisting boats at davits.

FENDERS —Lengths of spars cut up, or bundles of faggots tied together, and hung over the ship's side to prevent chafing against another vessel or against a wharf. The fenders of a boat are usually made of canvas, stuffed and neatly painted.

FIRE BACK.—This indicates that part of the exploded gases in the cylinder get into the inlet pipe when the inlet valve first opens and ignites the gas in the induction pipe. In cases of very fast-running engines, and with excessively weak inlet valve springs, the inlet may remain open till the end of the compression stroke, when part of the exploding charge may get back into the induction pipe.

FLAP VALVE.—A flat-faced valve hinged at one side.

FLARE.—The outward slope of the sides of a boat from the water-line to the gunwale.

FLASHPOINT (of a liquid).—The temperature at which a volatile liquid gives off inflammable vapour in sufficient quantity to ignite at the approach of a flame.

FLAT-ABACK.—When all the sails are blown with their after-surface against the mast, so as to give stern-way.

FLATTEN IN, TO.—The action of hauling in the aftmost clew of a sail to give it greater power of turning the vessel.

FLEMISH, TO.—To coil down a rope concentrically in the direction of the sun, or coil of a watch-spring, beginning in the middle without riders; but if there must be riding fakes they begin outside; the latter is the true French coil.

FLOORS.—Stouter transverse frames connecting the timbers from side to side with the keel.

FLOTSAM.—Goods floating from a wreck.

FLY.—The outer portion of a flag away from the staff.

FODDERING, OR FOTHERING is usually practised to stop a leak at sea. A heavy sail, as the sprit-sail, is closely thrummed with yarn and oakum, and drawn under the bottom; the pressure of the water drives the thrumming into the apertures.

FORE-FOOT.—The foremost piece of the keel, or timber which terminates the keel at the forward extremity, and forms a rest for the stem's lower end.

FORE PEAK —The extreme forward part of a vessel under the deck.

FULL AND BY.—Sailing close-hauled on a wind.

G

GANGWAY.—That part of a ship's side, and opening in her bulwarks, by which persons enter and depart, provided with a sufficient number of steps, or cleats, nailed upon the ship's side, nearly as low as the surface of the water, and sometimes furnished with a railed accommodation-ladder projecting from the ship's side, and secured by iron braces.

GARBOARD-STRAKE.—The first range of planking laid upon a ship's bottom, next the keel, to which it is nailed.

GASKET.—A cord or piece of plaited or other stuff, to secure furled sails to the spar.

GAUGE.—A device for measuring or comparing the dimensions of parts of machinery.

GLAND.—A piece of metal loosely encircling a rod or shaft for the purpose of keeping the packing material, through which the rod or shaft works, tight in place.

GOING FREE.—Sailing with the wind abeam.

GOVERNOR.—Mechanism controlled by the speed of the engine and arranged to cut down the supply of gas as soon as the speed exceeds a predetermined limit.

GOVERNOR, INERTIA.—A special type of governor usually described as the hit-and-miss type. An arm of the governor is utilised as a tappet rod to open a valve of the engine, and the position of the arm is controlled by a heavy ball or other weight so fitted that as soon as the engine speed reaches a certain limit the tappet changes its position and fails to open its valve.

GRAFTING.—An ornamental weaving of fine yarns, etc., over the strop of a block; or applied to the tapered ends of the ropes, and termed pointing.

GRAPNEL, OR GRAPLING.—A small anchor for boats, having a ring at one end, and four palmed claws at the other.

GRATINGS.—An open woodwork of cross battens and ledges forming cover for the hatchways, serving to give light and air to the lower decks.

GRIPES.—A broad plait formed by an assemblage of ropes, woven and fitted with thimbles and lanyards, used to steady the boats when hung in the davits, or upon the deck of a ship at sea. The gripes are fastened at their ends to ring-bolts in the deck, on each side of the bolt, whence, passing over her middle and extremities, they are set up by means of the lanyards.

GROUND SWELL.—A sudden swell preceding a gale, which rises along shore, often in fine weather, and when the sea beyond it is calm.

GRUB SCREW.—A small pointed screw used to maintain the relative position of two pieces of any mechanism, screwing into the first piece and bedding into a shallow pointed hole in the second.

GUDGEON PIN.—The spindle set diametrically across a piston and to which the connecting rod is attached.

GUDGEONS.—Hangings for rudder, each pair of which consists of gudgeon and pintle.

GUESS-WARP, OR GUEST-ROPE.—A rope carried to a distant object, in order to warp a vessel towards it, or to make fast a boat.

GUNWALE.—A longitudinal strip of hard wood used to stiffen the top of the sides of a boat. Among Thames builders this is sometimes termed *inwale*. In decked vessels it is usually termed *shelf*, and may be of either wood or steel.

GUY.—A rope used to steady a weighty body from swinging against the ship's side while it is hoisting or lowering, particularly when there is a high sea. Also a rope extended from the head of sheers, and made fast at a distance on each side to steady them.

H

HAIL.—To call another vessel.

HALYARD, HALLIARD.—A rope used for hoisting a sail or flag.

HAMMER, WATER.—The resistance of water in a pipe to a suddenly-applied force, tending to produce or arrest its motion, causing a blow like that of a hammer.

HAND.—A term often used for the word "man."

HARD-A-LEE.—The situation of the tiller when it brings the rudder hard over to windward.

HATCHWAY.—A square or oblong opening in the middle of the deck of a ship.

HAWSE HOLES.—Cylindrical holes cut through the bows of a ship on each side of the stem, through which the cables pass.

HEAD (of a liquid).—The height of its free surface above the point to which it is referred.

HEEL OF A MAST.—The lower end which either fits into the step attached to the keel, or in topmasts is sustained by the fid upon the trestle-trees.

HELICAL.—Shaped like a spiral, such as a screw thread or a coiled spring. Helical gear wheels are those having teeth set at an angle across the circumference of the wheel.

HIGH CARBON STEEL.—A steel containing a considerable percentage of carbon.

HIGH-TENSION DISTRIBUTOR.—See Index.

HOGGED.—Implies that the two ends of a ship's deck droop lower than the midship part, consequently, that her keel and bottom are so strained as to curve upwards. The term is therefore in opposition to that of "sagging."

HOIST (1).—To lift.

(2).—That portion of a flag next the staff.

(3).—A set of flags forming a signal.

HORN PLATE.—See "Bearer Arms."

HORNS.—The points of the jaws of booms or gaffs. Also the outer ends of the cross-trees.

HOT POT.—A system of ignition consisting of a small chamber initially heated by lamp and kept hot automatically by the explosions in the motor cylinder.

HOT TUBE.—A system of ignition depending on a small tube screwed into the engine cylinder and heated by a lamp.

HOUSING, OR HOUSE-LINE.—A small line formed of three fine strands, smaller than rope yarn; principally used for seizings of the block-strops, fastening the clews of sails to their bolt-ropes, and other purposes. (See "Marline.")

HOVE DOWN.—The situation of a ship when heeled or placed thus for repairs.

HOVE SHORT.—The ship with her cable hove taut towards her anchor.

HOVE TO, LYING TO.—Sailing vessel, with fore and aft rig, when lying nearly head to wind with her fore sheet hauled over to windward throwing the sail aback.

HUG, TO.—To hug the land is to sail as near it as possible, the land, however, being to windward. To hug the wind, is to keep the ship as close-hauled to the wind as possible.

HYDROCARBON.—A fuel composed of carbon in combination with hydrogen.

I

IMPEDENCE.—The opposition offered to the flow of an electric current by the induction of the circuit in which it flows.

INDUCED CURRENT.—A current due to induction.

INDUCTION (Electro-magnetic).—The generation of a potential difference in a conductor due to a current passing through an adjacent conductor or through the same conductor.

INERTIA.—Resistance of a body, increasing with its mass, to change of motion, whether in direction or velocity.

INERTIA GOVERNOR.—See "Governor."

INTERCOSTALS.—Short transverse members connecting two girders.

INWALE.—See "Gunwale."

IRIDIUM.—A metal which is very difficult to oxidise, and which is alloyed with platinum to give the requisite hardness to contact points.

IRONS, IN.—A sailing vessel is in irons when she is head to wind and will not pay off on either tack.

ISOTHERMAL (expansion or contraction of a gas).—A change of volume effected without change of temperature.

J

JACK.—A flag, the Union Jack; upper quarter of British ensign next the staff.

JACK-STAY.—See Index, *Masts and Sails, Names of.*

JAM, To.—To fix anything so that it cannot be freed without trouble and force.

JAW.—The inner, hollowed, semi-circular end of a gaff or boom, which presses against the mast; the points of the jaw are called "horns."

JETSAM.—Goods sunk.

JETTISON.—Goods thrown overboard.

JIB.—A large triangular sail, set on a stay at the bowsprit.

JIB-BOOM.—A continuation of the bowsprit forward.

JIG.—A contrivance (which may take any number of forms) for facilitating the machining of component parts of any piece of mechanism.

JOCKEY PULLEY.—An idle pulley used to guide or keep the tension on belt, or, in some cases, on a chain.

JOGGLE.—To cut a section out of one piece of timber to allow it to fit over another piece.

JOURNAL.—That portion of a shaft which turns in a bearing.

JUMPER.—See "Tappet."

JUNK PLATE, JUNK RING.—A plate or ring bolted on the top of a piston to keep the rings in place.

JURY-MAST.—A temporary or occasional mast erected in a ship in the place of one which has been carried away in a gale.

K

KAPOK.—A species of Australian vegetable fibre, like wool, used for stuffing cushions, etc.

KATHODE.—In a primary battery, the positive electrode. In any cell in which a current is passing through an electrolyte, the electrode by which the current leaves the cell.

KEDGE.—A small anchor used to warp a ship from one part of a harbour to another.

KEEL.—The backbone or foundation of a ship upon which the rest of her structure is built. In wooden ships it consists of squared lengths of suitable timber which are joined at the ends by strong scarphs. In iron ships there are various kinds, bar, side bar, and flat plate keels.

KEEP YOUR LUFF.—An order to the helmsman to keep the ship close to the wind.

KING PLANK.—The central plank of a deck, usually wider and occasionally stouter than the rest of the deck planks.

KINK.—An accidental curling twist, or doubling turn in a cable or rope.

KNEES.—Pieces of bent wood, iron or steel for connecting certain parts of vessels together, such as the beams or girders to the ribs or frames. In some cases the beams themselves are bent at the ends into knee shapes.

KNEES, HANGING.—Vertical knees connecting the deck beams with the timbers and side of the vessel.

KNEES, LODGING.—Horizontal knees connecting the deck beams with the shelf or gunwale and side of the vessel.

KNEES, QUARTER.—Knees connecting the after ends of the shelf or gunwale with the transom or archboard.

KNOT (1).—A measure of speed (*not* distance); one nautical mile per hour.

(2).—A division of log line to correspond with the period of the sand glass; so many knot divisions per turn of the glass gives the speed of the vessel in knots.

L

LANYARD.—A short piece of rope or line made fast to anything to secure it, or to serve as a handle.

LATITUDE.—Distance north or south from the Equator on the earth's surface.

LATITUDE, PARALLELS OF.—Imaginary lines parallel to the earth's equator.

LAY.—The twisting of a rope, as "hawser laid," similar to ordinary yacht's rope; "cable laid," usually three hawser laid ropes laid up together; may be laid right or left-handed.

LAYING OFF.—Making full-sized drawings of a vessel on floor of mould loft from small scale drawings.

LAY, To.—To come or go, as lay aloft, lay forward, lay aft, lay out.

L.B.P.—Length between perpendiculars, *i.e.*, that between the fore side of the stem and the after side of the stern post on deck.

LEAD (pronounced led).—See Index. There are several forms of patent leads for self-registering the depth of water

LEAD (pronounced leed).—See "Fairlead." The direction in which a line runs.

LEE.—It is the side opposite to that from which the wind is blowing.

LEEWAY.—The distance a vessel loses by drifting to leeward of her course.

LEVRINE.—A similar material to pantasote.

LEYDEN JAR.—A condenser made in the form of a plain jar, having tinfoil coatings both inside and outside.

LIE-TO, To.—To cause a vessel to keep her head steady, and as close to the wind as possible in a gale.

LIFTS.—See Index, *Masts and Sails, Names of.*

LIMBER HOLES.—The holes cut in the timbers and floor frames to allow free passage of the bilge water.

LIST, To.—To incline to one side.

L.O.A.—Length over all

LOAD WATER LINE.—The draught of water exhibited when the ship is properly loaded.

LOCKNUT.—A nut used to prevent another shaking loose.

LOG (1).—A book in which is kept a complete record of the vessel's movements, the state of the weather and sea, etc., and all that occurs during a voyage.

(2).—A contrivance for ascertaining the distance traversed by a vessel through the water or its speed. *Patent or Taffrail Log.*—A mechanical arrangement fitted on the stern and showing the distance on a dial. *Chip Log.*—A sector-shaped piece of wood attached to a line and dropped overboard, the time taken to run out a known length of line

taken and the speed of the vessel calculated therefrom. (See "Knot.")

LONGITUDE.—Distance east or west on the earth's surface; by Britons reckoned from the meridian of Greenwich.

LUFF.—The order to the helmsman to bring the ship's head up more to windward.

L.W.L.—Length on water line.

M

MAGNETIC FIELD.—A space under magnetic influence, conventionally represented as lines of force, these lines indicating by their direction the direction of the force, and by their number its intensity.

MAGNETO.—See Index.

MAKE FAST.—A term generally used for tying or securing ropes. To fasten.

MALLEABLE.—Used chiefly of a certain variety of cast iron; metal that can be hammered or bent cold.

MAN, TO.—To provide a competent number of hands for working a ship or boat, or any part of her gear.

MARLINE.—Small tarred twine.

MARLINE-SPIKE.—A taper-pointed steel spike, used for opening the strands of rope in splicing.

MEAN EFFECTIVE PRESSURE.—The average pressure exerted on a piston during its power stroke.

MEET HER.—The order to adjust the helm, so as to check any further movement of the ship's head in a given direction.

MERIDIAN.—An imaginary line on the earth in a direction due north and south.

MESH (gear wheels in mesh).—Toothed wheels in gear, so that one drives the other.

MESH (of a net).—The spaces between the strings.

METACENTRE.—In a ship lying perfectly in equilibrium, or upright, a line drawn perpendicularly to the keel passes through both the centre of buoyancy and the centre of gravity of the ship. When the ship is heeled to any angle, the centre of buoyancy, owing to the change in the form of the ship immersed, is shifted out of that perpendicular line towards the side to which the ship is heeled in proportion to the angle of heel. A vertical line drawn from this new centre of buoyancy cuts the perpendicular line drawn through the centre of gravity, and the point at which it cuts it is called the Metacentre. The distance between that point, or the metacentre, and the centre of gravity is called the metacentric height, and upon the measure of that height depends the leverage, or power of the ship, to right herself when the force which heels her (such as wind) is withdrawn, or to prevent her heeling further if the force is continued. If the centre of buoyancy shifts so much that the vertical line drawn from it cuts the beforementioned perpendicular line at or below the centre of gravity the righting power is lost, and the ship will capsize; therefore to be safe the metacentric point must always be above the centre of gravity.

M.E.P.—Mean effective pressure.

METAL.—A term usually applied to brass, bronze, etc., in contradistinction to iron or steel.

MIDSHIPS.—The middle part of the vessel, either with regard to her length or breadth.

MILE.—See "Admiralty Mile," "Statute Mile," "Nautical Mile."

MISSING STAYS.—To fail in going about from one tack to another.

MOTORMAN.—The British marine equivalent of the automobile foreign word *chauffeur;* the man who has charge of the motor.

MOULD.—A framework made to the shape of the section of a boat, and used in building.

MOULD (in casting).—A sand shape into which molten metal is poured.

MOULDED DEPTH.—From top of floor timbers to top side of deck beams amidships.

MOULDING.—The depth of a timber or part of the frame of a boat.

MOULD-LOFT.—A long building, on the floor of which the intended vessel is laid off from the several drawings in full dimensions.

MOUSING.—A lashing connecting the bill of a hook with the shank.

M.P.—Motor power, as measured by the Marine Motor Association formula.

M. TERMINAL (of a coil).—A contraction of the French word "masse," meaning "earth." In its accepted sense the "M" terminal of a coil is the one to be connected to the make-and-break gear.

N

NAUTICAL MILE.—6,082.6 feet, usually taken at Admiralty standard of 6,080 In general use, Admiralty mile of 6,080 feet.

NEEDLE VALVE.—A valve of extremely small aperture, closed by a fine-pointed rod or spindle.

NEGATIVE POLE.—An empirical term for one pole of a battery (see "Positive Pole"). The negative pole of a battery is usually indicated by the symbol —.

NETTLES.—Small line used for seizings, and for hammock-clews.

N.H.P.—Nominal horse power.

NIP.—A short turn in a rope

NODE.—A point in which a curve cuts itself.

NORMAL TO.—At right angles to

O

O.A—Over all; extreme length wherever taken, including moulding or figure-head

OFF AND ON.—When a ship beating to windward approaches the shore by one board, and recedes from it when on the other.

OFF SETS—Measurements taken, say, from centre line of vessel to the intersection of a waterline and transverse section

OFFER UP.—To fix a thing temporarily in the place it is intended to take.

OHM.—See Index.

OIL, CRUDE.—See "Crude Oil."

OIL, RESIDUAL.—See "Residual Oil."

OIL, SHALE—See "Shale."

OPEN HAWSE.—When a vessel rides by two anchors without any cross in her cables.

OTTO CYCLE.—See Index.

OUTWALE.—See "Rubbing Band," a term seldom used.

P

PAINTER.—A rope attached to the bows of a boat, used for making her fast.

PANTASOTE.—A patent waterproof material, somewhat like thin leather, used for covering cushions, etc.

PARAFFIN WAX.—A very highly insulating wax, forming part of the residue of crude oil after distillation.

PARALLEL (Connections).—Any electrical conductors so arranged that the current from a common source divides into two or more branches passing through them. Of batteries, two or more cells having all their positives connected together, and all their negatives connected together. Such a battery has a capacity equal to the sum of the capacities of each cell separately.

PARBUCKLE.—To move a body by rolling it along by means of a rope passed around it.

PAY.—To coat or cover, or to fill a crack with waterproof composition, such as marine glue or pitch.

PAY OFF.—(1) (sailing), to allow the ship's head to fall away from the direction of the wind.

(2).—(Of a vessel), discharging the crew on conclusion of a voyage or commission.

PEGAMOID.—A similar material to pantosote.

PIG-IRON.—An oblong mass of cast-iron or lead used for ballast.

PINION.—The smaller of two gear wheels meshing together

PINTLE.—A vertical pin in the rudder post to hold the rudder. Pin of rudder hanging. (See "Gudgeon.")

PIPE BERTH.—A folding bed, the frame of which is made of gas (or similar) piping.

PITCH OF PROPELLER.—Distance in line of ship of one complete turn of blade or thread. The theoretical distance through which a propeller would move if turned through one revolution in a solid body.

PLIMSOLL MARK.—A sign consisting of a circle cut by a horizontal straight line to indicate the limit of load allowed for a vessel.

PLUNGER.—The piston working in a pump barrel.

POLARIZE.—The collection of bubbles of gas, products of electrolysis, on the kathode of a primary battery; these bubbles being non-conductors of electricity obstruct the flow of the current, and so weaken the battery.

PORT.—(1) A harbour.

(2).—The left-hand side of a vessel. (See also "Starboard.")

(3).—Opening into a cylinder.

PORT-CHARGES, OR HARBOUR DUES.—Charges levied on vessels resorting to a port.

POSITIVE POLE.—An empirical term, denoting that pole or terminal of a battery from which the current is supposed to flow. As a matter of fact, there is nothing to prove that electricity really flows either from positive to negative or vice versâ. The positive pole is usually indicated by the symbol +.

POTENTIAL DIFFERENCE.—The difference of electrical pressure, measured in volts.

PRESSURE (mean effective).—See "Mean Effective Pressure."

PRICKER.—Small marline-spike, with wooden handle, used in small boats.

PRIMARY BATTERY.—See Index.

PRIMARY WINDING (of induction coil).—See Index.

PRIME MOVER.—Any mechanism for converting energy into motion.

PRIMING (a pump).—Putting water in it to make it draw.

PRIMING (steam engine).—The passage of water with the steam from the boiler to the cylinder.

PROPELLER, AREA OF.—The sum of the areas of the blades of the propeller.

PURCHASE.—Any means of increasing the power available for moving heavy weights, etc.; generally an arrangement of ropes and pulley blocks. See also Index, *Masts and Sails, Names of.*

Q

QUARANTINE.—A seclusion from a free communication with the inhabitants of any country.

QUARTER KNEE.—See "Knees."

R

RABBET.—The groove cut in the keel, stem, etc., to make the joint with the planking.

RACE.—(1) (tide) Broken water caused by a very strong-running tide, in some cases termed "Overfall."

(2) (Engine).—To run at excessive speed.

(3).—Column of water discharged from propeller.

RECIPROCATING.—The act of moving alternately forward and backward along a straight line.

REEFING.—Reducing the size of the sail by rolling up a portion.

REEF POINTS.—Short pieces of cord sewn into a sail with ends on opposite sides of the sail; used for tying round the rolled up sail when reefing.

RENDERING.—Any rope, hawser, or cable is "rendered" by easing it round the bitts.

RESIDUAL OIL.—Black, treacly-looking oil remaining after the lighter constituents—petrol, benzine, paraffin, etc.—have been distilled oft.

RESONANCE.—Two or more independent vibrations coming into step with each other.

ROWLOCK (pronounced rulluck).—A U-shaped piece of metal, with a shank fitting into a hole in the gunwale, in which an oar is placed when rowing.

RIDGE-ROPE.—The centre rope of an awning.

ROVE.—Threaded through; to pass rope through block, hole, or fair-lead.

ROVES (pronounced rooves).—Slightly conical metal rings, on which the inner ends of nails are turned or clenched to prevent them drawing out.

ROYAL MAST.—See Index, *Masts and Sails, Names of.*

RUBBING BAND.—Sometimes termed an "outwale. This is a projecting moulding of hard wood, frequently shod with iron or metal to protect the vessel's side.

RUN OF VESSEL.—The narrowing in of the underwater body of the vessel to the stern.

RUN OUT A WARP.—To carry a hawser out from the ship by a boat, and fasten it to some distant place to remove the ship towards that place, or to keep her steady whilst her anchors are lifted, etc.

S

SAGGING.—A term applied when the centre part of a ship droops.

SAMSON POSTS.—Almost the same as "bollards," which see. Generally of wood, in pairs, and connected about half-way up by a cross piece, which extends beyond the posts at both ends.

SCANTLINGS.—Dimensions of the principal structural parts of a vessel, and also of machinery.

SCARPH.—A form of joint in the framing or

[illegible] of a vessel, in which the two ends are [illegible] to a long taper and overlapped.

SCAVENGE (of a motor engine).—To clear out the burnt gases from the cylinder.

SCREW.—See "Propeller."

SCRIEVE.—To mark with a sharp-pointed tool. Also *scribe* or *scrive*.

SCUTTLE.—A small hole or port cut either in the deck or side of a ship, generally for ventilation.

SEA MILE.—Same as nautical mile.

SECONDARY BATTERY.—See "Accumulator."

SECONDARY WINDING (of an induction coil).—See Index.

SECTION.—A plane through a vessel at right angles to her water-line.

SEIZE (1) (of two pieces of machinery in rubbing contact).—To stick hard together.

(2).—To bind two parts of rope or other substances together with small line

SERIES CONNECTION (Batteries connected in).—The + of one cell is connected to the — of the next, and so on for any number of cells, leaving a + and a — terminal at each end. The voltage of a battery connected in this way is the sum of the voltages of each of the cells separately.

SERIES CONNECTION (of any pieces of apparatus).—So arranged that the same current, from any source, passes through all of them.

SERVE.—To wind round tightly with small twine the end or other part of a rope or spar.

SERVING MALLET.—A wood or metal mallet with a round T head, having a groove along the length of the head to take the rope being served; the serving twine is wound round rope and mallet head, and the mallet worked round the rope to draw the serving tight.

SHALE OIL.—Crude mineral oil obtained from shale beds.

SHEAVE.—The wheel in a pulley or block.

SHEAVE (Eccentric).—A circular disc placed eccentrically on a shaft.

SHEER.—The longitudinal curve of a ship's decks or sides upwards towards the ends. A perfectly straight ship is said to have "no sheer." Should the ends droop, a ship is said to have "reverse sheer."

SHEER STRAKE, OR TOP STRAKE.—The uppermost plank in a vessel's side.

SHEET.—The rope attached to the lower after corner of a fore and aft sail to hold it in against the wind, or both lower corners of square topsails, etc.

SHELF.—See "Gunwale."

SHIP'S PAPERS.—Documents descriptive of a vessel, her owners, cargo, destination and other particulars necessary for the court of instance.

SHROUDS.—Wire ropes securing the mast to the sides of the vessel.

SIDING.—The width of a vessel's framing as opposed to depth or moulding.

SILL OF A DOCK.—The timber at the base against which the gates shut; the depth of water which will float a vessel in or out of it is measured from it to the surface.

SKIN EFFECT.—A phenomena met with in rapidly alternating electric currents; such currents appear to be only conducted by the outer skin of any conductor, the resistance of a very thin tube being the same as that of a solid bar of the same external diameter.

SKIN FRICTION.—The rubbing resistance offered by water to the surface of a boat passing through it; 2lb. per sq. foot (clean paint); resistance due to skin friction varies as 1.8 power of speed.

SLACK IN STAYS.—Slow in going about.

SLIP (of propeller).—The percentage ratio of the actual advance to the theoretical advance in the direction of the vessel.

SLIP RING.—A metal ring on a rotating shaft from which electric current can be collected by means of a brush in rubbing contact with the ring.

SMALL END (of a connecting rod).—The end carrying the bearing which is attached to the piston or piston rod; sometimes known as the gudgeon pin bearing or crosshead bearing.

SNIFTING VALVE (in a pump).—An automatic valve for admitting air to prevent hammering in the pipe; an automatic valve admitting air and, in some engines, water, during the suction stroke.

SOAPSTONE.—A talc-like mineral used as insulating material of a sparking-plug.

SOLENOID.—A single coil of wire having considerable induction.

SOUNDINGS.—Depths of water as taken with the lead line. *In Soundings*, in water whose depth can be taken with the hand lead line.

SPAN.—A rope with both ends made fast, so that a purchase may be hooked to its bight.

SPANKER.—See Index, *Masts and Sails, Names of*.

SPAULS.—Battens fixed across the top of a boat to prevent the sides spreading when building.

SPELL.—The period wherein one or more men are employed in particular duties demanding continuous exertion.

SPIGOT.—A plug or peg fitting into a corresponding socket; used to maintain the relative positions of two adjacent bodies.

SPILINGS.—The measurements taken from the edge of the spiling batten to the edge of the last plank, in order to get the shape of the next plank.

SPROCKET.—The larger of two wheels, of which one drives the other by means of a chain.

SPUR WHEEL.—The larger of two gear wheels meshing together.

STARBOARD.—The right-hand side of a vessel. The order to the steersman, "Starboard" (or "Port"), means move the *helm* (tiller) to starboard (or port), which will have the effect of bringing the ship's head round in the *opposite* direction.

START.—To start, applied to liquids, is to empty. To "start a tack or sheet"; to slack it off, as in tacking or manœuvring. "Raise tacks and sheets."

STARTING TORQUE.—See "Torque."

STAY.—A rope supporting a spar, usually in a fore and aft direction.

STAYSAIL.—A triangular sail hoisted upon a stay.

STAYS, IN.—A sailing vessel changing course from one tack to another with her head directly to the wind and sails flapping. *Missing Stays* is failure to change over from one tack to the other, necessitating paying off again on the same tack.

STEEL.—Iron combined with carbon and sometimes with manganese, tungsten, chromium, and phosphorus.

STEEL, CHROME.—Steel containing chromium; this is a glass-hard metal.

STEEL, HARD.—Steel containing a high percentage of carbon and cooled suddenly from a bright red heat.

STEEL, MILD.—Steel combined with a smaller percentage of carbon, and capable of much bending without fracture.

STEM.—The foremost piece uniting the bows of a ship.

STEM BAND, KEEL BAND, ETC.—Iron or metal bands to protect these parts.

STEP.—The block in which the heel of a mast seats.

STERN POST.—The main stern frame of a vessel. (In the case of power vessels a second similar post, called the rudder post, is sometimes fitted abaft the propeller to carry the rudder.)

STERN-SHEETS.—The after part of an open boat where the passengers sit; also the seats in that portion.

STERN TUBE.—The tube passing through the stern post or bottom of a vessel in which the propeller shaft revolves.

STRAKE.—A longitudinal planking in the skin of a vessel.

STRANDED.—A rope is stranded when one of its strands is broken by chafing, or by a strain. A vessel is stranded when driven on shore.

STREAM THE BUOY.—To let the buoy fall into the water before letting go the anchor.

STRINGER.—Longitudinal strip of timber, worked on the inside of the timbers or frames, usually at the bilge.

STRUM.—A strainer box.

SULPHATING.—See Index, *Accumulators*.

SUMP.—A small box or pit into which water or other liquid may drain.

SUN AND PLANET GEAR.—See "Epicyclic Gear."

SWAB.—A sort of mop-head, formed of rope-yarns of old junk, used for cleaning and drying the decks

SWEAT.—To join two pieces of metal with solder.

T

TABERNACLE.—A wood or steel case to support a lowering mast.

TACK (1).—*To tack* in sailing is to change the course of the vessel, to bring the wind from one side to the other by way of right ahead. *Port* (*or starboard*) *tack*.—Having the wind on the port (or starboard) side.

(2).—Of a sail.—The forward lower corner of any sail. See also Index, *Masts and Sails, Names of*.

TAIL BLOCK.—A rope-stropped block, having an end of rope attached to it as a tail, by which it may be fastened to any object at pleasure.

TAPPET.—An intermediate member in any mechanism used to transmit the motion of a cam to the part to be actuated.

TARPAULIN.—Canvas well covered with tar or paint to render it waterproof.

TENSION (High).—An electrical conductor is in a condition of high tension when its electrical pressure is of such magnitude as to cause a "jump" spark of appreciable length. In electrical engineering, at a pressure of 500 volts or over.

Low.—A condition of electrical pressure of less magnitude than 500 volts. (See "High Tension.")

THERMAL.—Appertaining to heat.

THERMAL EFFICIENCY.—See "Efficiency."

THROTTLE.—A device for regulating the supply of gas passing from the carburetter to the cylinder by opening or closing the passage through the induction pipe.

THRUST-BLOCK.—A heavy piece of metal fitted with grooves, between which rings on the propeller shaft work, thereby transmitting motion to the ship.

THWART.—A transverse seat in a boat.

TIDE RACE.—See "Race."

TIMBERS.—The transverse frames supporting and connecting the planking.

TONNAGE.—The cubical contents of a vessel allowing 100 cubic feet to the ton.

Gross Tonnage is the total cubic capacity of every enclosed space on board ship.

Net Tonnage is that space available for cargo only.

Register Tonnage is that measured and entered on the ship's register; it is practically the same as net tonnage.

TORQUE.—The force tending to produce rotation.

TORQUE, STARTING.—The initial turning effort of an engine starting from rest.

TORTS.—Private wrongs either to persons or property afloat.

TRANSOM.—The transverse piece forming the after end of a square-stern boat.

TRANSOM BERTH.—American misnomer for any fixed berth.

TREMBLER.—See Index.

TRIM.—The difference between the draughts at the stern and bow.

TRIP GEAR.—See Index. A device for breaking the circuit inside a cylinder fitted with low-tension ignition.

TUBE IGNITION.—See "Hot Tube."

TUMBLE HOME.—The inward curve of the sides of a boat from the water-line to the gunwale.

TUNGSTEN.—A rare metal used in the manufacture of self-hardening steel.

TYE.—See Index, *Masts and Sails, Names of*.

U

UNRIG, TO.—To dismantle a ship of her standing and running rigging.

UP WITH THE HELM.—Put it a-weather.

U SECTION.—Section of a boat's hull rounded at the keel like the letter "U."

V

VANGS.—See Index, *Masts and Sails, Names of*.

VEER AND HAUL.—The wind is said to veer and haul when it alters its direction; thus it is said to veer aft and haul forward.

VEER AWAY THE CABLE, TO.—To slack and let it run out.

VEER, TO.—To let out, to pay out.

VOLATILE.—That which will easily evaporate.

VOLT.—See Index.

VOLTMETER.—An instrument for measuring the voltage of any source of electrical energy.

V SECTION.—Section of a vessel's hull like the letter "V."

W

WAKE.—The transient, generally smooth, track impressed on the surface-water by a ship's progress.

WATER HAMMER.—See "Hammer."

WATER-LOGGED.—The state of a ship full of water, having such a buoyant cargo that she does not sink.

WATER-WAYS.—The strake on the inside of a vessel in line with the edge of the upper deck, forming a gutter-way to lead the water off the deck to the scuppers.

WAY.—*Under way.*—A vessel is "under way," or has "way on," when moving ahead or astern through the water.

In way of.—In the line of or near; frequently applied in respect of the engine in a vessel.

WAYS.—The sloping baulks or guides upon which the cradle slides when launching a vessel.

WEATHER-HELM.—A ship is said to carry a weather-helm when she is inclined to gripe, or come too near the wind, and therefore requires the helm to be kept constantly a little to windward.

WEIGH.—To "weigh" the anchor is to get it out of the ground and hanging by its cable from the vessel.

A vessel is sometimes said to be "under weigh" as soon as her anchor is clear of the ground, though not necessarily moving.

WELL.—The part of the vessel where any water that leaks into the ship can collect, and from thence it is pumped overboard. In small craft the term is applied to the cockpit or undecked space generally abaft the cabin.

WETTED SURFACE.—The superficial area of a hull which is immersed. The greater this area the greater will be the skin friction as the boat moves through the water. (See "Skin Friction.")

WHEEL.—The American misnomer for a screw propeller.

WIPE CONTACT.—See Index.

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